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**Harding**

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(54) **SYSTEMS AND METHODS FOR GENERATING AN IMPROVED DIFFRACTION PROFILE**

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***G01N 23/207*** (2006.01)

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(58) **Field of Classification Search** ................... 378/57, 378/86, 88, 90, 70, 71, 82, 83

See application file for complete search history.

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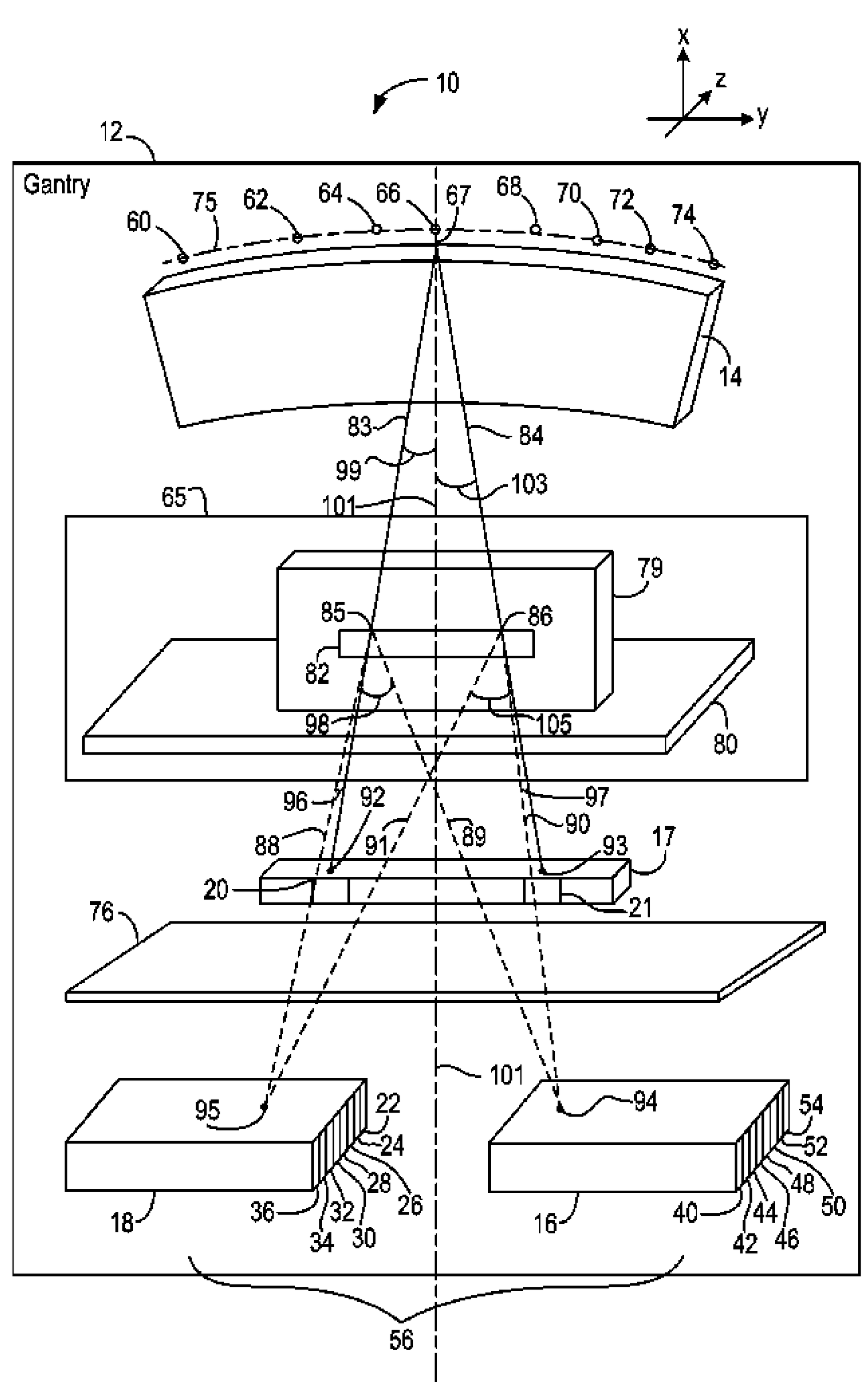
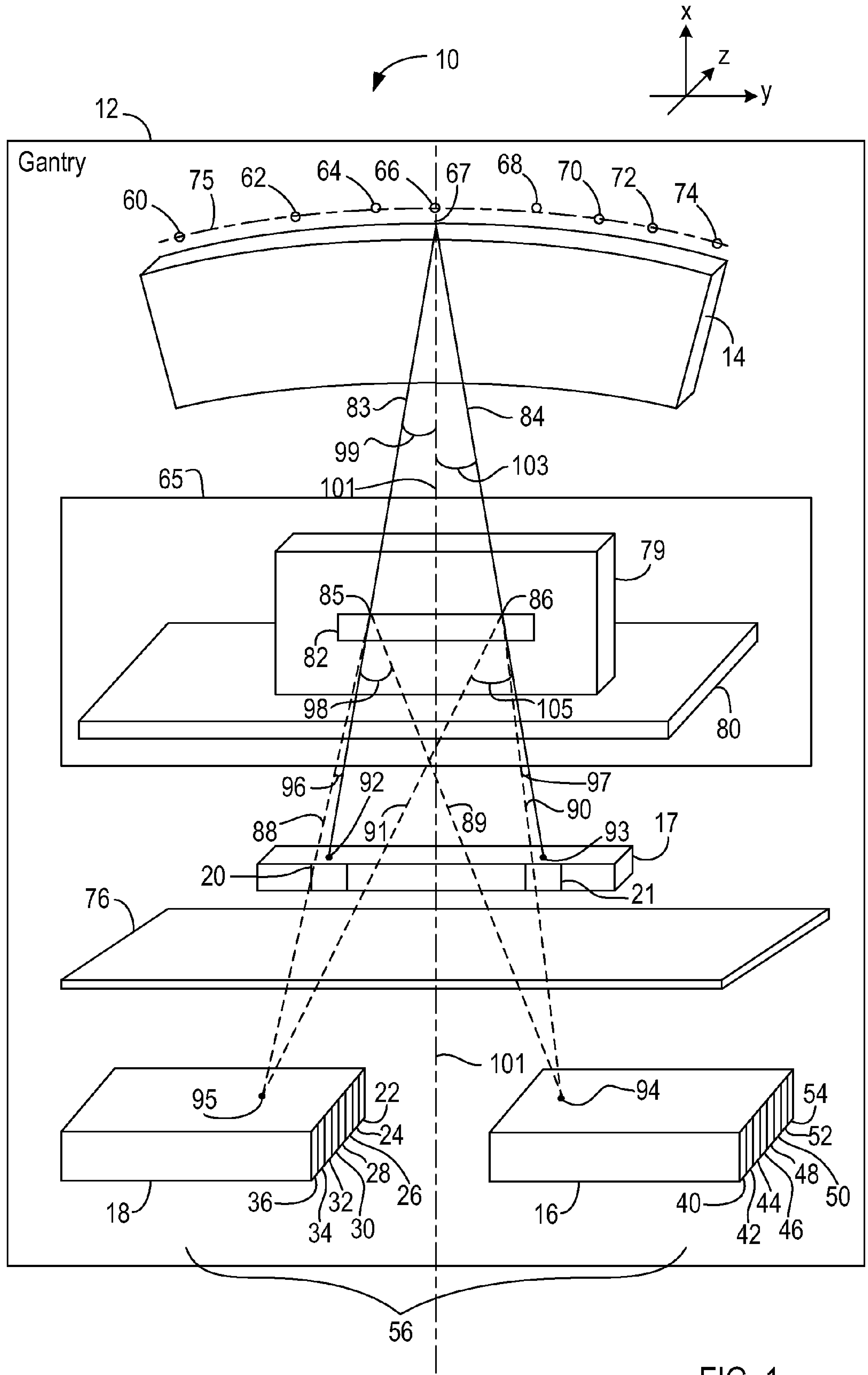
(57) **ABSTRACT**

A system for generating an improved diffraction profile is described. The system includes at least one x-ray source configured to generate x-rays and a primary collimator outputting a first x-ray beam to a first focus point and a second x-ray beam to a second focus point. The primary collimator generates the first and second x-ray beams from the x-rays. The system further includes a container, and a first scatter detector configured to detect a first set of scattered radiation generated upon intersection of the first x-ray beam with the container and to detect a second set of scattered radiation generated upon intersection of the second x-ray beam with the container. An angle of scatter of the first set of scattered radiation detected by the first scatter detector is at most half of an angle of scatter of the second set of scattered radiation detected by the first scatter detector.

**20 Claims, 12 Drawing Sheets**





10
x
z
y
12
Gantry
60
75
62
64
66
67
68
70
72
74
14
83
84
99
103
101
65
79
85
86
82
98
105
80
96
92
97
88
91
89
90
93
17
20
21
76
101
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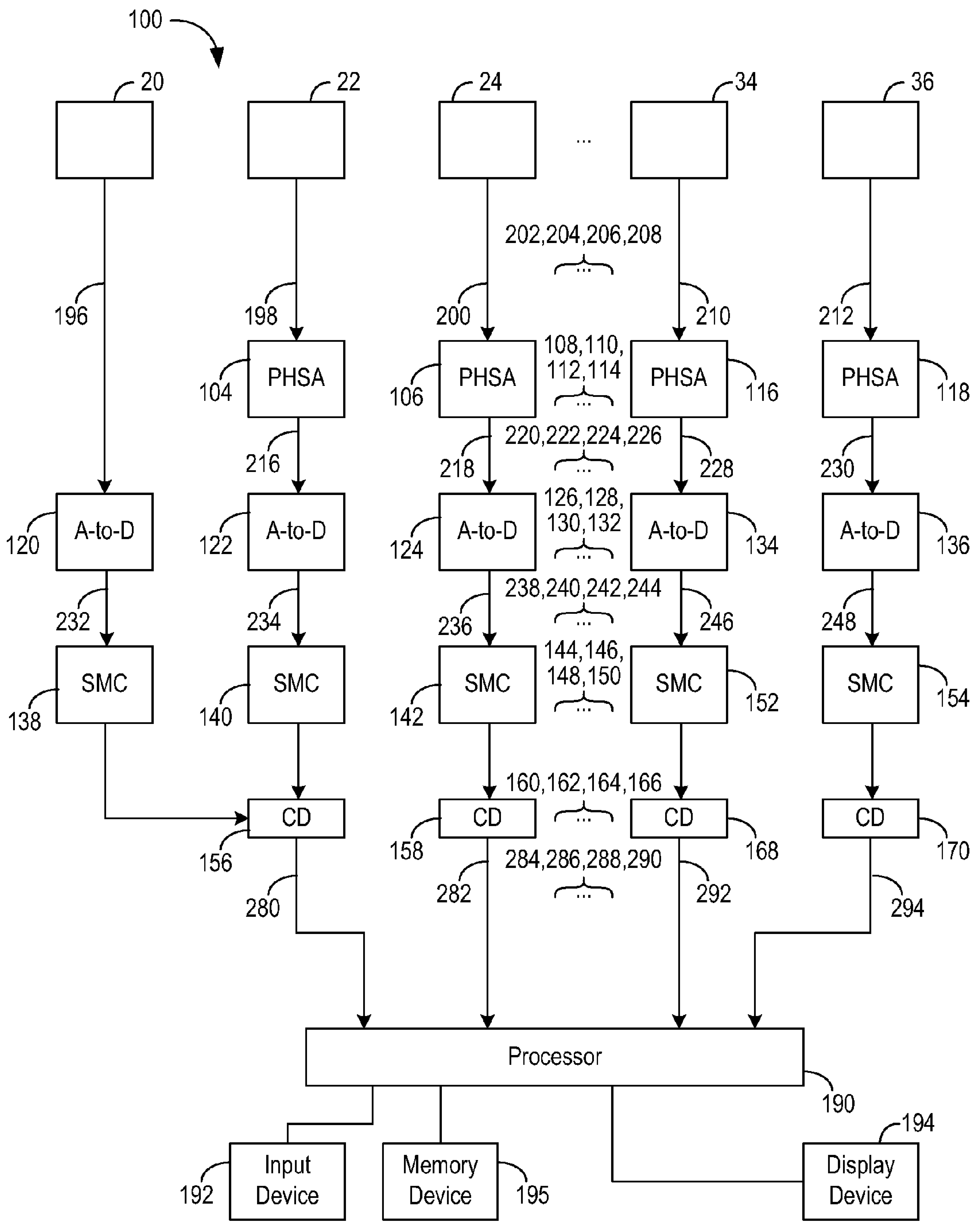
56


FIG. 1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238,240,242,244
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SMC
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142
144,146,
148,150
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154
160,162,164,166
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CD
156
158
168
170
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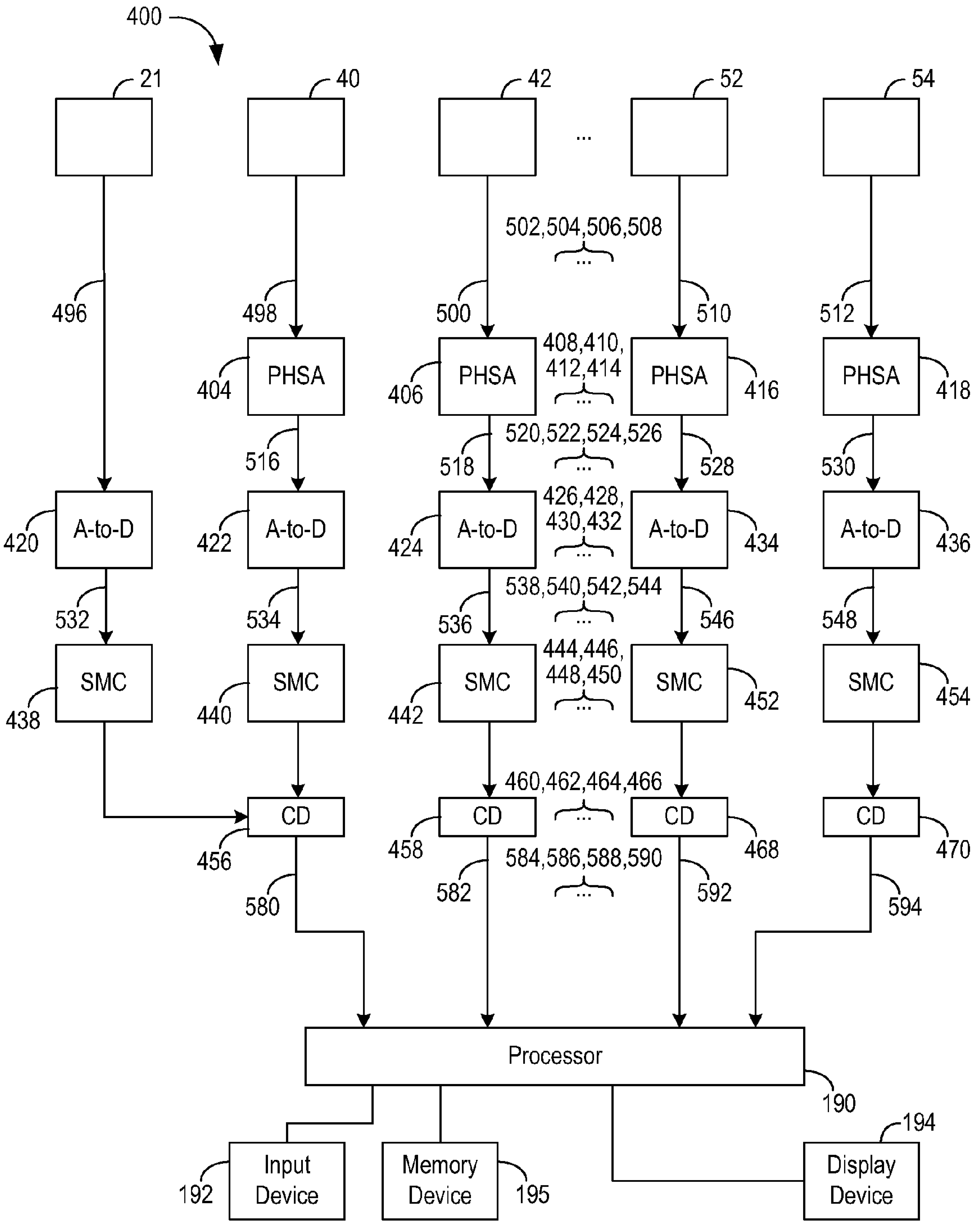
Processor
190
194
Input
Device
Memory
Device
Display
Device
192
195

FIG. 2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404
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408,410,
412,414
416
418
516
518
520,522,524,526
528
530
A-to-D
A-to-D
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420
422
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426,428,
430,432
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536
538,540,542,544
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548
SMC
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SMC
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SMC
438
440
442
444,446,
448,450
452
454
460,462,464,466
CD
CD
CD
CD
456
458
468
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580
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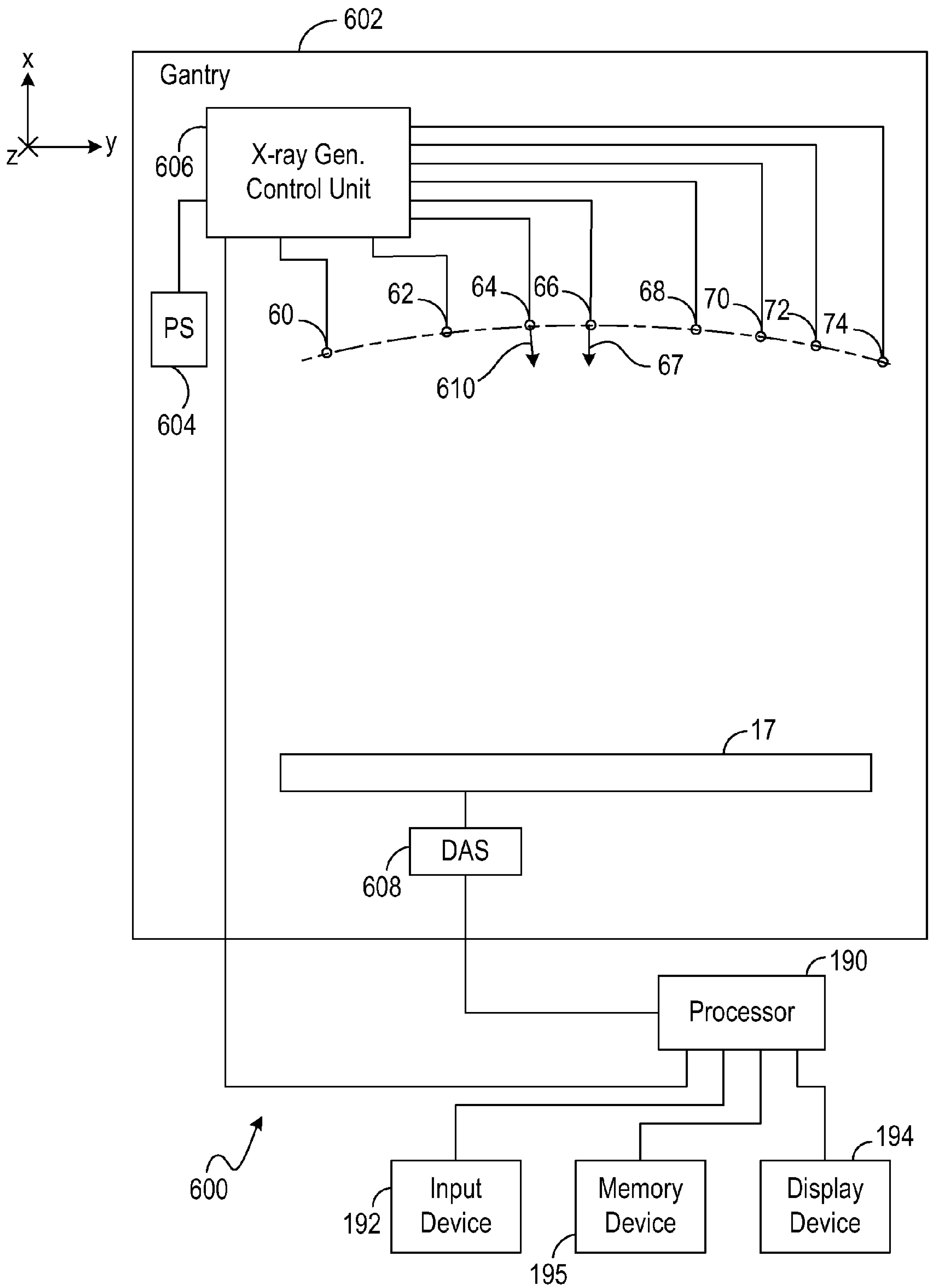
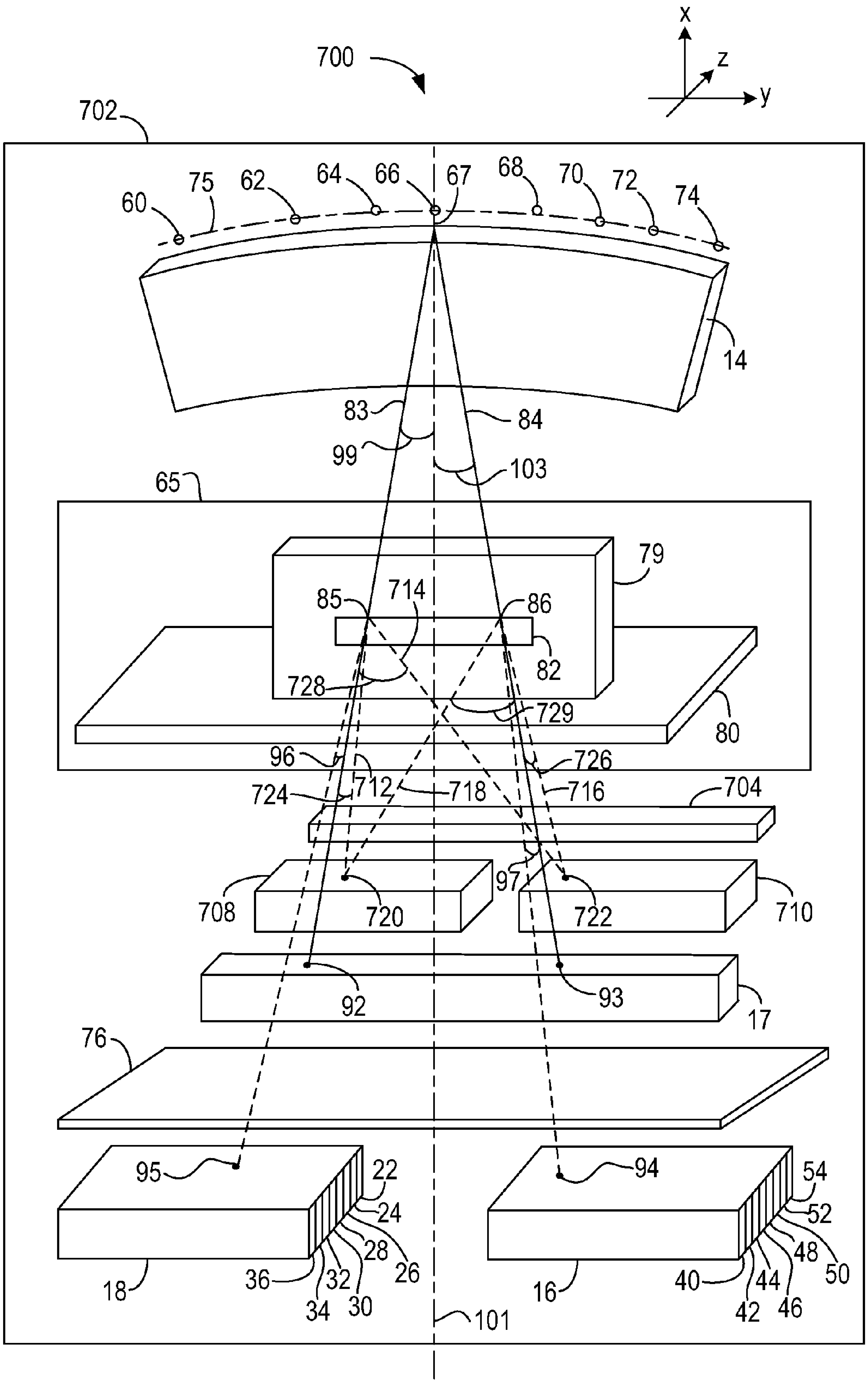
584,586,588,590
592
594
Processor
190
194
Input Device
Memory Device
Display Device
192
195

FIG. 3



602
x
y
z
Gantry
606
X-ray Gen.
Control Unit
PS
604
60
62
64
66
68
70
72
74
610
67
17
DAS
608
190
Processor
600
194
Input
Device
192
Memory
Device
195
Display
Device


FIG. 4



700
702
x
z
y
60
75
62
64
66
67
68
70
72
74
14
83
84
99
103
65
79
85
714
86
82
728
729
80
96
726
724
712
718
716
704
97
708
720
722
710
92
93
17
76
95
94
22
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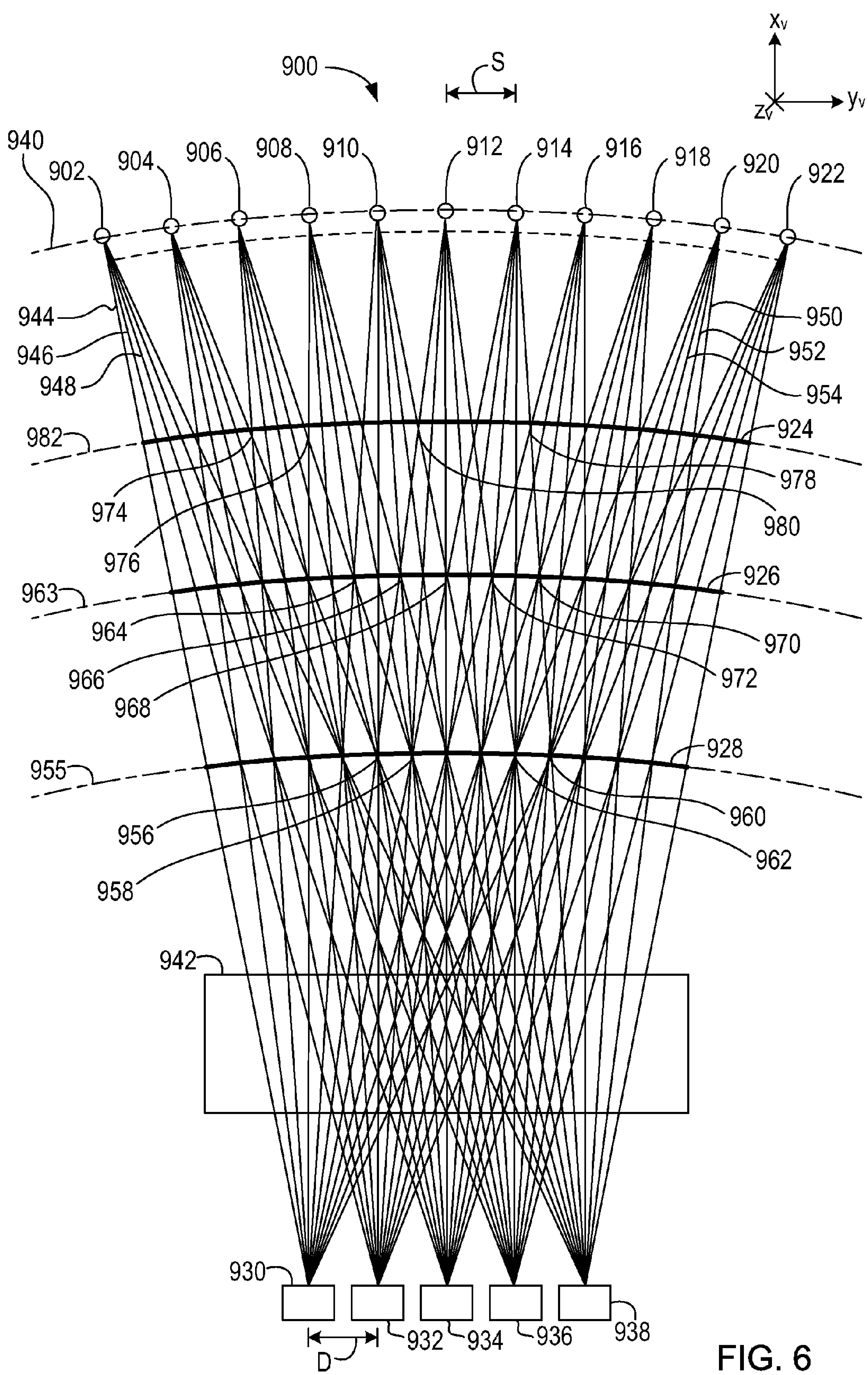
42
46
101


FIG. 5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S
$x_v$
$y_v$
$z_v$
940
902
904
906
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922
944
946
948
950
952
954
982
924
974
976
978
980
963
926
964
966
968
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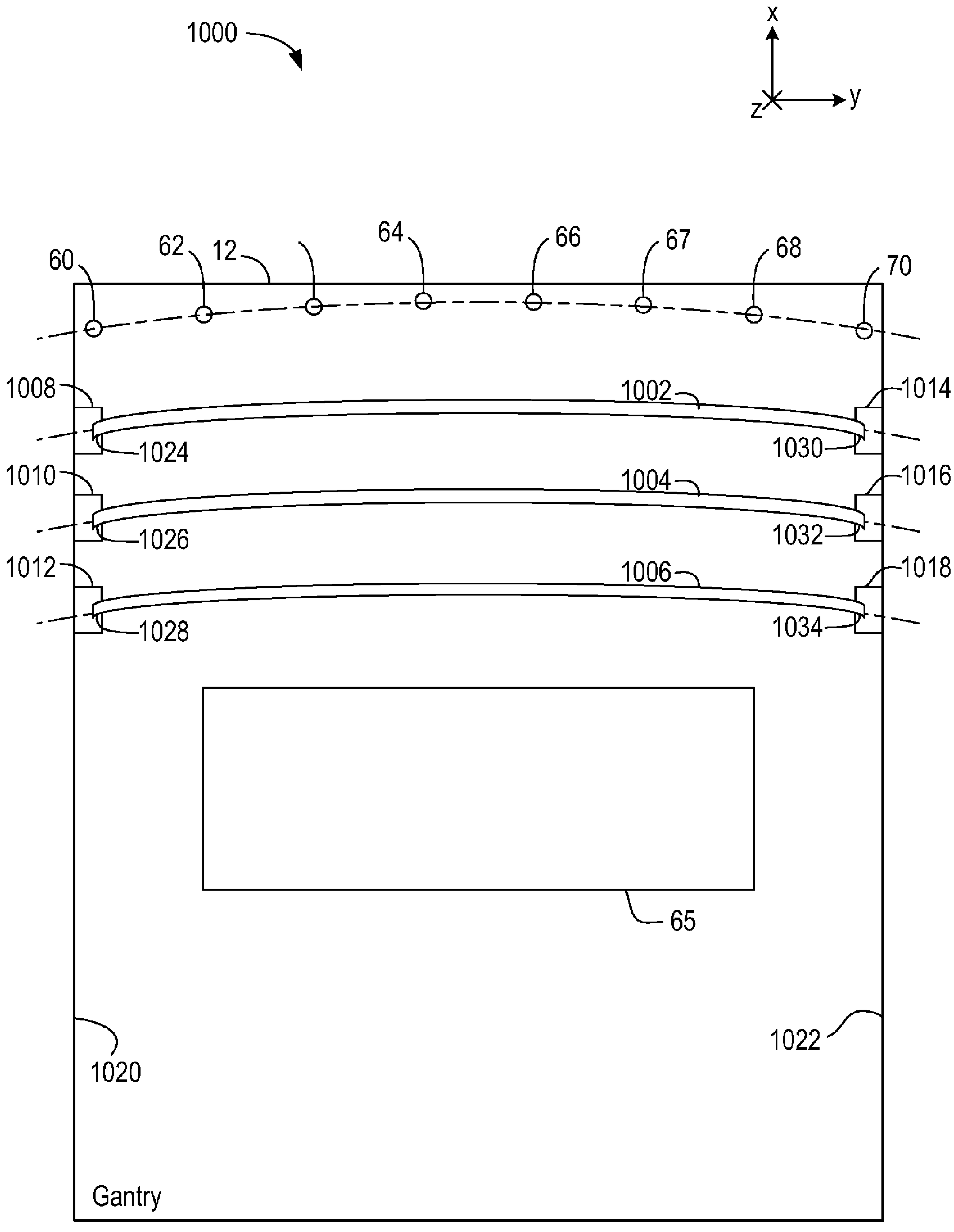
D

FIG. 6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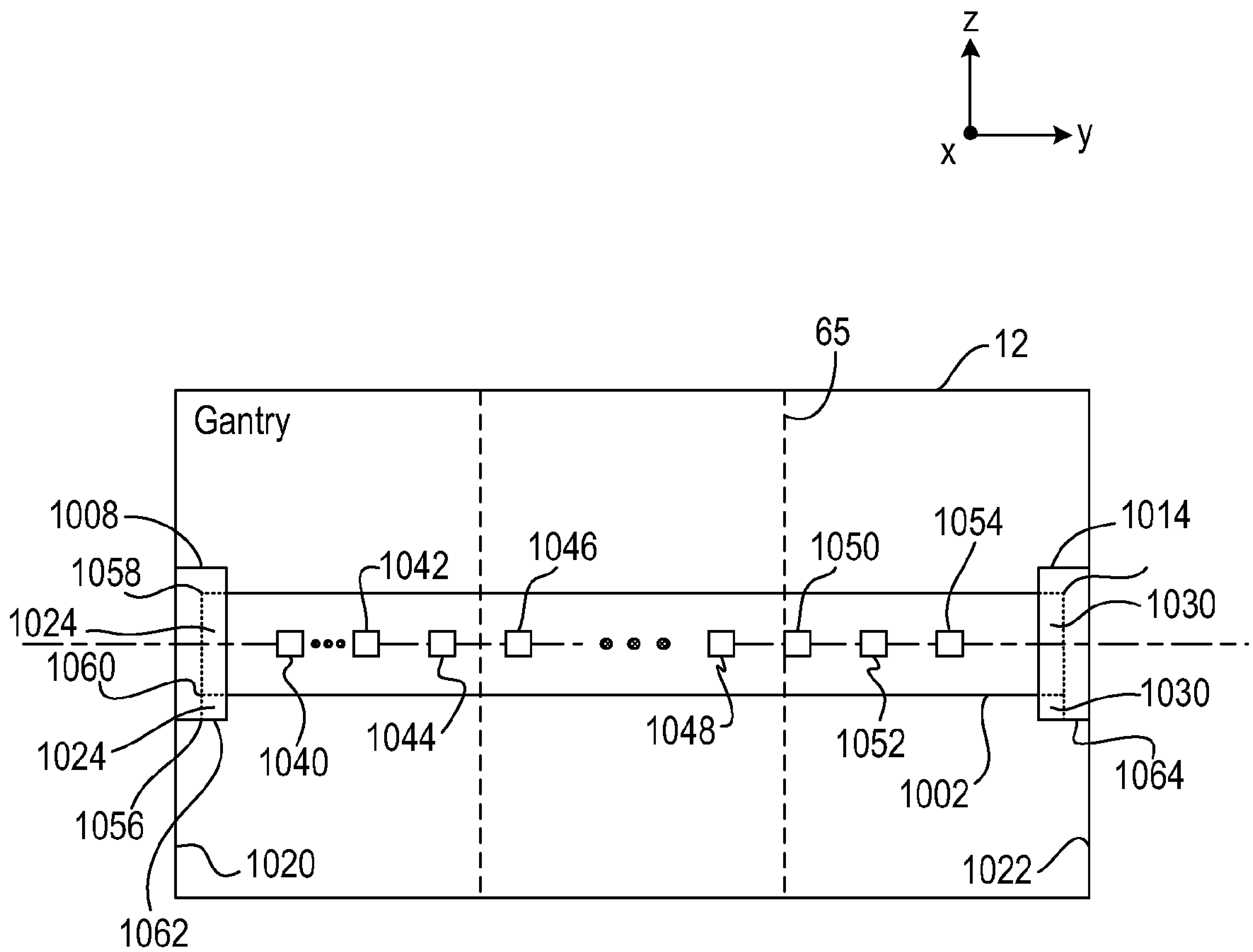
x
y
z
60
62
12
64
66
67
68
70
1008
1002
1014
1024
1030
1010
1004
1016
1026
1032
1012
1006
1018
1028
1034
65
1020
1022
Gantry

FIG. 7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y
x
65
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Gantry
1008
1058
1024
1060
1024
1056
1062
1042
1046
1040
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1054
1052
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1064
1020
1022

FIG. 8

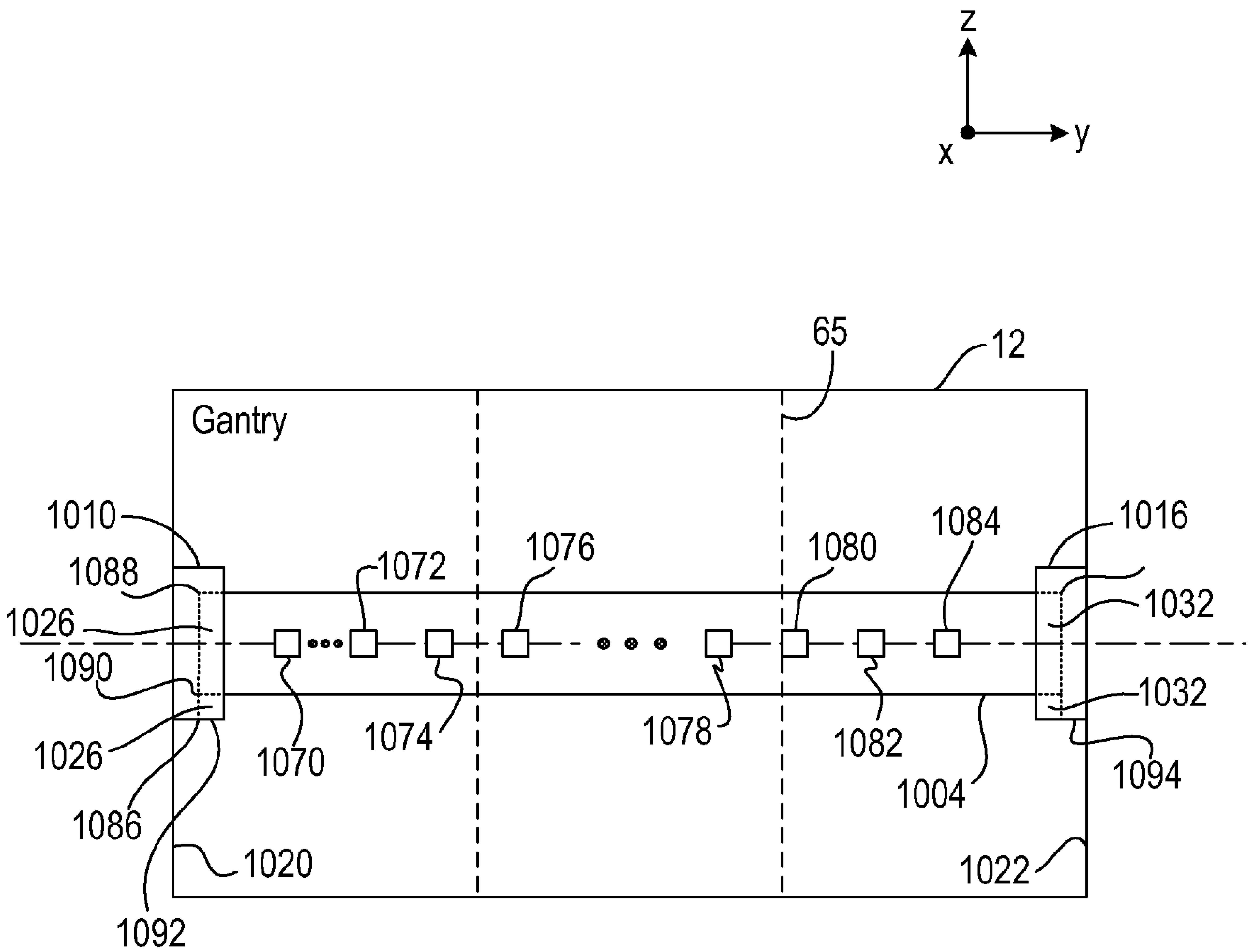
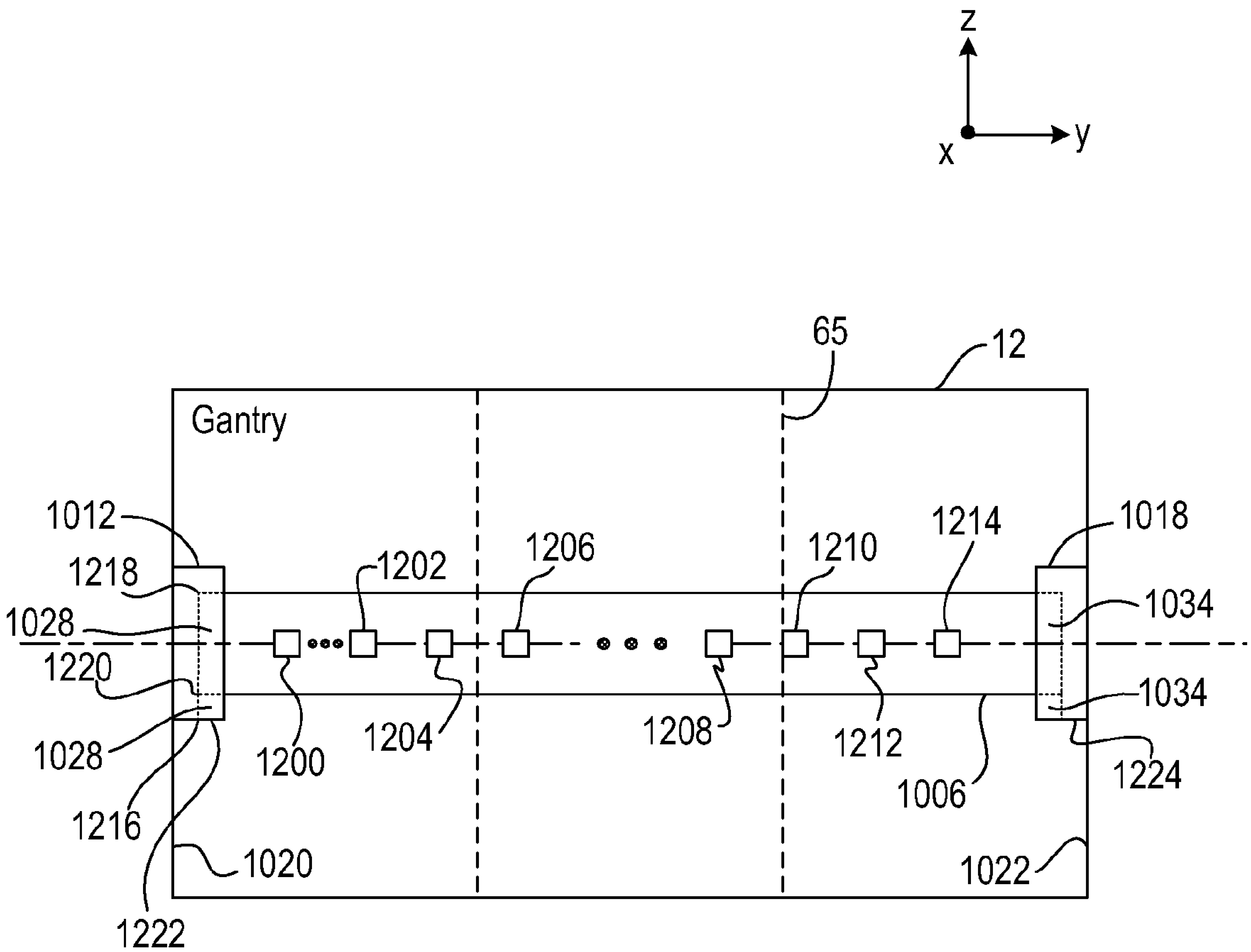
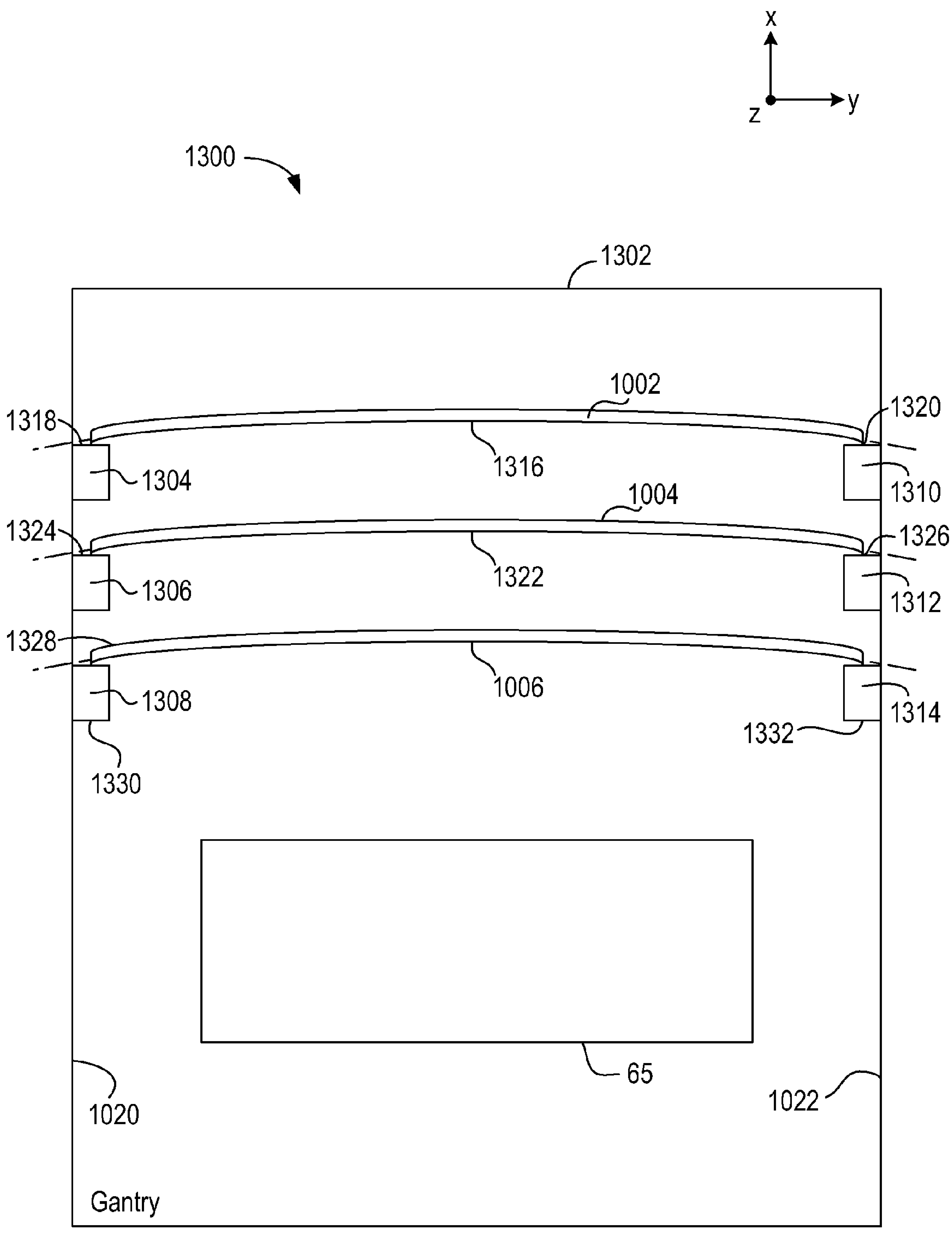

z
y
x
65
12
Gantry
1010
1016
1088
1072
1076
1080
1084
1032
1026
1090
1026
1070
1074
1078
1082
1032
1094
1004
1086
1020
1022
1092

FIG. 9



z
y
x
65
12
Gantry
1012
1018
1218
1202
1206
1210
1214
1028
1034
1220
1034
1028
1200
1204
1208
1212
1224
1006
1216
1020
1022
1222


FIG. 10



x
y
z
1300
1302
1002
1318
1320
1316
1304
1310
1004
1324
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1312
1328
1006
1308
1314
1332
1330
65
1020
1022
Gantry


FIG. 11

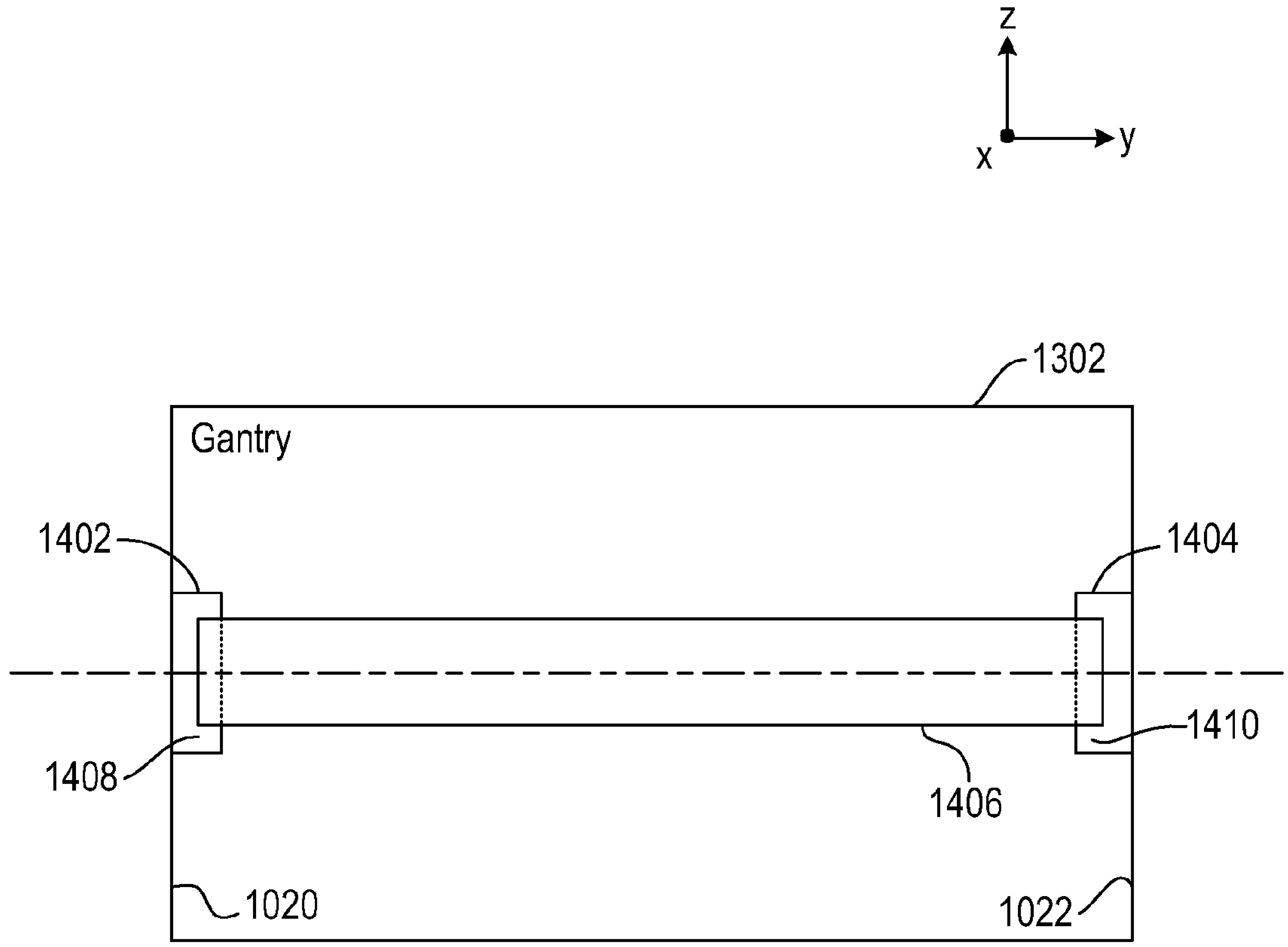


FIG. 12

# SYSTEMS AND METHODS FOR GENERATING AN IMPROVED DIFFRACTION PROFILE

## BACKGROUND OF THE INVENTION

This invention relates generally to systems and methods for generating a diffraction profile and more particularly to systems and methods for generating an improved diffraction profile.

The events of Sep. 11, 2001 instigated an urgency for more effective and stringent screening of airport baggage. The urgency for security expanded from an inspection of carry-on bags for knives and guns to a complete inspection of checked bags for a range of hazards with particular emphasis upon concealed explosives. X-ray imaging is a widespread technology currently employed for screening. However, existing x-ray baggage scanners, including computed tomography (CT) systems, designed for detection of explosive and illegal substances are unable to discriminate between harmless materials in certain ranges of density and threat materials like plastic explosive.

A plurality of identification systems based on a plurality of x-ray diffraction (XRD) techniques provide an improved discrimination of materials compared to that provided by the x-ray baggage scanners. The XRD identification systems measure a plurality of d-spacings between a plurality of lattice planes of micro-crystals in materials.

However, the XRD identification systems are inefficient because the XRD identification systems consume a high amount of power. Moreover, it is difficult for the XRD identification systems to examine a large suitcase.

## BRIEF DESCRIPTION OF THE INVENTION

In one aspect, a system for generating an improved diffraction profile is described. The system includes at least one x-ray source configured to generate x-rays and a primary collimator outputting a first x-ray beam to a first focus point and a second x-ray beam to a second focus point. The primary collimator generates the first and second x-ray beams from the x-rays. The system further includes a container, a first scatter detector configured to detect a first set of scattered radiation generated upon intersection of the first x-ray beam with the container and to detect a second set of scattered radiation generated upon intersection of the second x-ray beam with the container. An angle of scatter of the first set of scattered radiation detected by the first scatter detector is at most half of an angle of scatter of the second set of scattered radiation detected by the first scatter detector.

In another aspect, a system for generating an improved diffraction profile is described. The system includes at least one x-ray source configured to generate x-rays and a primary collimator outputting a first x-ray beam to a first focus point and a second x-ray beam to a second focus point. The primary collimator generates the first and second x-ray beams from the x-rays. The system further includes a container, and a first scatter detector configured to detect a first set of scattered radiation generated upon intersection of the first x-ray beam with the container and to detect a second set of scattered radiation generated upon intersection of the second x-ray beam with the container. An angle of scatter of the first set of scattered radiation detected by the first scatter detector is at most half of an angle of scatter of the second set of scattered radiation detected by the first scatter detector. The system also includes a processor coupled to the first scatter detector and configured to generate a portion of a diffraction profile from the first and second sets of scattered radiation detected by the first scatter detector



In yet another aspect, a method for generating an improved diffraction profile is described. The method includes generating x-rays by activating at least one x-ray source and outputting, by a primary collimator, a first x-ray beam to a first focus point and a second x-ray beam to a second focus point. The primary collimator generates the first and second x-ray beams from the x-rays. The method further includes detecting, by a first scatter detector, a first set of scattered radiation generated upon intersection of the first x-ray beam with a container and detecting, by the first scatter detector, a second set of scattered radiation generated upon intersection of the second x-ray beam with the container. An angle of scatter of the first set of scattered radiation detected by the first scatter detector is at most half of an angle of scatter of the second set of scattered radiation detected by the first scatter detector.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an isometric view of an embodiment of a system for generating an improved diffraction profile of a substance.

FIG. **2** is a block diagram of an embodiment of a system for generating an improved diffraction profile of a substance.

FIG. **3** is a block diagram of an embodiment of a system for generating an improved diffraction profile of a substance.

FIG. **4** is a block diagram of an embodiment of a system for generating an x-ray image.

FIG. **5** is an isometric view of an alternative embodiment of a system for generating an improved diffraction profile of a substance.

FIG. **6** is a diagram of illustrating an embodiment of a virtual system for developing a primary collimator of the system of FIG. **1**.

FIG. **7** is a diagram of an embodiment of a system implementing the primary collimator.

FIG. **8** is a top view of an embodiment of a gantry of the system of FIG. **1**.

FIG. **9** is another top view of an embodiment of the gantry.

FIG. **10** is yet another top view of an embodiment of the gantry.

FIG. **11** is a diagram of an alternative embodiment of a gantry.

FIG. **12** is a top view of the gantry of FIG. **11**.

## DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is an isometric view of an embodiment of a system **10** for generating an improved diffraction profile of a substance. System **10** includes a gantry **12**. Gantry **12** includes a primary collimator **14**, a scatter detector **16**, a transmission detector **17**, a scatter detector **18**, and a secondary collimator **76**. Each scatter detector **16** and **18** is a segmented semiconductor detector.

Transmission detector **17** includes a plurality of detector elements, such as detector elements **20** and **21**. Scatter detector **18** includes a plurality of detector cells or detector elements **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36** for detecting coherent scatter. Scatter detector **16** includes a plurality of detector cells or detector elements **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54** for detecting coherent scatter. Each of scatter detectors **16** and **18** include any number, such as, ranging from and including 5 to 1200, of detector elements. For example, scatter detector **18** includes a number, such as ranging from and including 5 to 40, of detector elements in a z-direction parallel to a z-axis, and a number, such as ranging from and including 1 to 30 detector elements in a y-direction parallel to a y-axis. An x-axis, the y-axis, and the z-axis are located within an xyz co-ordinate system. The x-axis is perpendicular to the y-axis and the z-axis, and the y-axis is perpendicular to the z-axis, and the x-axis is parallel to an x-direction. X-ray sources, of system **10**, including x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, and transmission detector **17** form an inverse single-pass multi-focus imaging system. X-ray sources, of system **10**, including x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, have an inverse fan-beam geometry that includes a symmetric location of the x-ray sources relative to the z-axis. A number of detector elements within scatter detector **16** is the same as a number of detector elements within scatter detector **18**.

Scatter detector **16** is separate from scatter detector **18**. For example, scatter detector **16** has a housing that is separate from a housing of scatter detector **18**. As another example scatter detectors **16** and **18** are separated from each other by a gap. As yet another example, a shortest distance **56** between a center of scatter detector **16** and a center of scatter detector **18** ranges from and including 40 millimeters (mm) to 200 mm. Each of scatter detector **16**, scatter detector **18**, and transmission detector **17** are located in the same yz plane. The yz plane is formed by the y-axis and the z-axis. Each of scatter detector **16** and scatter detector **18** is separate from transmission detector **17** by a shortest distance ranging from and including 30 mm to 60 mm in the z-direction.

Gantry **12** further includes a plurality of x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**. X-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** are located parallel to and coincident with an arc **75**. It is noted that in an alternative embodiment, system **10** includes a higher number, such as 10 or 20, or alternatively a lower number, such as 4 or 6, of x-ray sources than that shown in FIG. **1**. A center of transmission detector **17** is located at a center of circle having arc **75**. Each x-ray source **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** is an x-ray source that includes a cathode and an anode. Alternatively, each x-ray source **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** is an x-ray source that includes a cathode and all x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** share a common anode.

A container **79** is placed on a support **80** between x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** and scatter detectors **16** and **18**. Container **79** and support **80** are located within an opening **65** of gantry **12**. Examples of container **79** include a bag, a box, and an air cargo container **79**. Examples of each x-ray source **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** include a polychromatic x-ray source. Container **79** includes a substance **82**. Examples of substance **82** include an organic explosive, an amorphous substance having a crystallinity of less than twenty five percent, a quasi-amorphous substance having a crystallinity at least equal to twenty-five percent and less than fifty percent, and a partially crystalline substance having a crystallinity at least equal to fifty percent and less than one-hundred percent. Examples of the amorphous, quasi-amorphous, and partially crystalline substances include a gel explosive, a slurry explosive, an explosive including ammonium nitrate, and a special nuclear material. Examples of the special nuclear material include plutonium and uranium. Examples of support **80** include a table and a conveyor belt. An example of each scatter detector **16** and **18** includes a segmented detector fabricated from Germanium.

X-ray source **66** emits an x-ray beam **67** in an energy range, which is dependent on a voltage applied by a power source to x-ray source **66**. Primary collimator **14** generates two primary beams **83** and **84**, such as pencil beams, upon collimating x-ray beam **67** from x-ray source **66**. In an alternative embodiment, primary collimator **14** collimates x-ray beam **67** received from x-ray source **66** to generates a plurality, such as three or four, primary beams. A number of primary beams generated by primary collimator **14** is equal to or alternatively greater than a number of scatter detectors on one side of transmission detector **17** and on one side of the y-axis. Primary beams **83** and **84** pass through a plurality of points **85** and **86** on substance **82** within container **79** arranged on support **80** to generate scattered radiation **88**, **89**, **90**, and **91**. For example, primary beam **83** passes through point **85** to generate scattered radiation **88** and **89**. As another example, primary beam **84** passes through point **86** to generate scattered radiation **90** and **91**.

Secondary collimator **76** is located between support **80** and a set of scatter detectors **16** and **18**. Secondary collimator **76** includes a number of collimator elements, such as sheets, slits, or laminations, to ensure that scattered radiation arriving at scatter detectors **16** and **18** have constant scatter angles with respect to primary beams **83** and **84** and that a position of scatter detectors **16** and **18** permits a depth in container **79** at which the scattered radiation originated to be determined. For example, the collimator elements of secondary collimator **76** are arranged parallel to a direction of scattered radiation **88** and of scattered radiation **90** to absorb scattered radiation that is not parallel to the direction of the scattered radiation **88** and of scattered radiation **90**.

The number of collimator elements in secondary collimator **76** provided is equal to or alternatively greater than a number of detector elements of any one of scatter detectors **16** and **18** and the collimator elements are arranged such that scattered radiation between neighboring collimator elements is incident on one of the detector elements. The collimator elements of scatter detectors **16** and **18** are made of a radiation-absorbing material, such as, steel, copper, silver, or tungsten.

Underneath support **80**, there is arranged transmission detector **17**, which measures an intensity of primary beam **83** at a point **92** on transmission detector **17** and an intensity of primary beam **84** at a point **93** on transmission detector **17**. Moreover, underneath support **80**, there are arranged scatter detectors **16** and **18** that measure photon energies of scattered radiation received by scatter detectors **16** and **18**. Each of scatter detectors **16** and **18** measures the x-ray photons within scattered radiation received by scatter detectors **16** and **18** in an energy-sensitive manner by outputting a plurality of electrical output signals linearly dependent on a plurality of energies of the x-ray photons detected from within the scattered radiation. Scatter detector **16** measures scattered radiation **90** received at a point **94** on scatter detector **16** and scatter detector **18** measures scattered radiation **88** received at a point **95** on scatter detector **18**. An example of a shortest distance between points **85** and **95** includes a distance ranging from and including 900 mm to 1100 mm. An example of a distance between points **95** and **92** includes a distance ranging from and including 25 mm to 80 mm.

Scatter detectors **16** and **18** detect scattered radiation to generate a plurality of electrical output signals. Scatter detector **16** detects scattered radiation **90** generated upon intersection of primary beam **84** with point **86**. Moreover, scatter detector **16** detects scattered radiation **89** generated upon intersection of primary beam **83** with point **85**. Scatter detector **18** detects scattered radiation **88** generated upon intersection of primary beam **83** with point **85**. Moreover, scatter detector **18** detects scattered radiation **91** generated upon intersection of primary beam **84** with point **86**. A scatter angle **96** formed between primary beam **83** and scattered radiation **88** is equal to a scatter angle **97** formed between primary beam **84** and scattered radiation **90**. An example of each of scatter angles **96** and **97** includes an angle ranging from and including 0.025 radians to 0.045 radians. An example of a scatter angle **98** formed between primary beam **83** and scattered radiation **89** ranges from and including 0.05 radians to 0.09 radians. Moreover, an example of a scatter angle **105** formed between primary beam **84** and scattered radiation **91** ranges from and including 0.05 radians to 0.09 radians. Scatter angle **98** is at least twice of each scatter angle **96** and **97** and scatter angle **105** is at least twice of each scatter angle **96** and **97**. An angle **99** formed by primary beam **83** with respect to a center **101** between scatter detectors **16** and **18** is equal to an angle **103** formed by primary beam **84** with respect to center **101**. In another alternative embodiment, system **10** includes additional scatter detectors other than scatter detectors **16** and **18**. The additional scatter detectors are placed on a side of transmission detector **17** that is the same as a side of placement of scatter detectors **16** and **18**. Moreover, the additional scatter detectors are the same as scatter detectors **16** and **18**. For example, any one of the additional scatter detectors have the same number of detector elements as that of any of scatter detectors **16** and **18**.

FIG. **2** is diagram of an embodiment of a system **100** for generating an improved diffraction profile of a substance. System **100** includes detector element **20** of transmission detector **17**, scatter detector elements **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36**, a plurality of pulse-height shaper amplifiers (PHSA) **104**, **106**, **108**, **110**, **112**, **114**, **116**, and **118**, a plurality of analog-to-digital (A-to-D) converters **120**, **122**, **124**, **126**, **128**, **130**, **132**, **134**, and **136**, a plurality of spectrum memory circuits (SMCs) **138**, **140**, **142**, **144**, **146**, **148**, **150**, **152**, and **154** allowing pulse height spectra to be acquired, a plurality of correction devices (CDs) **156**, **158**, **160**, **162**, **164**, **166**, **168**, and **170**, a processor **190**, an input device **192**, a display device **194**, and a memory device **195**. As used herein, the term processor is not limited to just those integrated circuits referred to in the art as a processor, but broadly refers to a computer, a microcontroller, a microcomputer, a programmable logic controller, an application specific integrated circuit, and any other programmable circuit. The computer may include a device, such as, a floppy disk drive or CD-ROM drive, for reading data including the methods for developing a primary collimator from a computer-readable medium, such as a floppy disk, a compact disc-read only memory (CD-ROM), a magneto-optical disk (MOD), or a digital versatile disc (DVD). In another embodiment, processor **190** executes instructions stored in firmware. Examples of display device **194** include a liquid crystal display (LCD) and a cathode ray tube (CRT). Examples of input device **192** include a mouse and a keyboard. Examples of memory device **195** include a random access memory (RAM) and a read-only memory (ROM). An example of each of correction devices **156**, **158**, **160**, **162**, **164**, **166**, **168**, and **170** include a divider circuit. Each of spectrum memory circuits **138**, **140**, **142**, **144**, **146**, **148**, **150**, **152**, and **154** include an adder and a memory device, such as a RAM or a ROM.

Detector element **20** is coupled to analog-to-digital converter **120**, and detector elements **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36** are coupled to pulse-height shaper amplifiers **104**, **106**, **108**, **110**, **112**, **114**, **116**, and **118**, respectively. Detector element **20** generates an electrical output signal **196** by detecting primary beam **83** and detector elements **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36** generate a plurality of electrical output signals **198**, **200**, **202**, **204**, **206**, **208**, **210**, and **212** by detecting scattered radiation. For example, detector element **22** generates electrical output signal **198** for each scattered x-ray photon incident on detector element **22**. Each pulse-height shaper amplifier amplifies an electrical output signal received from a detector element. For example, pulse-height shaper amplifier **104** amplifies electrical output signal **198** and pulse-height shaper amplifier **106** amplifies electrical output signal **200**. Pulse-height shaper amplifiers **104**, **106**, **108**, **110**, **112**, **114**, **116**, and **118** have a gain factor determined by processor **190**.

An amplitude of an electrical output signal output from a detector element is proportional to an energy of an x-ray quantum that is detected by the detector element to generate the electrical output signal. For example, an amplitude of electrical output signal **196** is proportional to an energy of an x-ray quantum in primary beam **83** detected by detector element **20**. As another example, an amplitude of electrical output signal **198** is proportional to an energy of an x-ray quantum within scattered radiation that is detected by detector element **22**.

A pulse-height shaper amplifier generates an amplified output signal by amplifying an electrical output signal generated from a detector element. For example, pulse-height shaper amplifier **104** generates an amplified output signal **216** by amplifying electrical output signal **198** and pulse-height shaper amplifier **106** generates an amplified output signal **218** by amplifying electrical output signal **200**. Similarly, a plurality of amplified output signals **220**, **222**, **224**, **226**, **228**, and **230** are generated. An analog-to-digital converter converts an output signal from an analog form to a digital form to generate a digital output signal. For example, analog-to-digital converter **120** converts electrical output signal **196** from an analog form to a digital format to generate a digital output signal **232** and analog-to-digital converter **122** converts amplified output signal **216** from an analog form to a digital format to generate a digital output signal **234**. Similarly, a plurality of digital output signals **236**, **238**, **240**, **242**, **244**, **246**, and **248** are generated by analog-to-digital converters **124**, **126**, **128**, **130**, **132**, **134**, and **136**, respectively. A digital value of a digital output signal generated by an analog-to-digital converter represents an amplitude of energy of a pulse of an amplified output signal. Each pulse is generated by an x-ray quantum, such as an x-ray photon. For example, a digital value of digital output signal **234** output by analog-to-digital converter **122** is a value of an amplitude of a pulse of amplified output signal **216**.

An adder of a spectrum memory circuit adds a number of pulses in a digital output signal. For example, when analog-to-digital converter **122** converts a pulse of amplified output signal **216** into digital output signal **234** to determine an amplitude of the pulse of amplified output signal **216**, an adder within spectrum memory circuit **140** increments, by one, a value within a memory device of spectrum memory circuit **140**. Accordingly, at an end of an x-ray examination of substance **82**, a memory device within a spectrum memory circuit stores a number of x-ray quanta detected by a detector element. For example, a memory device within spectrum memory circuit **142** stores a number of x-ray photons detected by detector element **24** and each of the x-ray photons has an amplitude of energy or alternatively an amplitude of intensity that is determined by analog-to-digital converter **124**.

A correction device receives a number of x-ray quanta that have a range of energies and are stored within a memory device of one of spectrum memory circuits **140**, **142**, **144**, **146**, **148**, **150**, **152**, and **154**, and divides the number by a number of x-ray quanta having the range of energies received from a memory device of spectrum memory circuit **138**. For example, correction device **156** receives a number of x-ray photons having a range of energies from a memory device of spectrum memory circuit **140**, and divides the number by a number of x-ray photons having the range received from a memory device of spectrum memory circuit **138**. Each correction device outputs a correction output signal that represents a range of energies within x-ray quanta received by a detector element. For example, correction device **156** outputs a correction output signal **280** representing an energy spectrum or alternatively an intensity spectrum within x-ray quanta detected by detector element **22**. As another example, correction device **158** outputs correction output signal **282** representing an energy spectrum within x-ray quanta detector element **24**. Similarly, a plurality of correction output signals **284**, **286**, **288**, **290**, **292**, and **294** are generated by correction devices **160**, **162**, **164**, **166**, **168**, and **170**, respectively.

It is noted that a number of pulse-height shaper amplifiers **104**, **106**, **108**, **110**, **112**, **114**, **116**, and **118** changes with a number of scatter detector elements **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36**. For example, five pulse-height shaper amplifiers are used for amplifying signals received from five scatter detector elements. As another example, four pulse-height shaper amplifiers are used for amplifying signals received from four scatter detector elements. Similarly, a number of analog-to-digital converters **120**, **122**, **124**, **126**, **128**, **130**, **132**, **134**, and **136** changes with a number of detector elements **20**, **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36** and a number of spectrum memory circuits **138**, **140**, **142**, **144**, **146**, **148**, **150**, **152**, and **154** changes with the number of detector elements **20**, **22**, **24**, **26**, **28**, **30**, **32**, **34**, and **36**.

FIG. **3** is a diagram of an embodiment of a system **400** for generating an improved diffraction profile of a substance. System **400** includes detector element **21** of transmission detector **17**, scatter detector elements **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54**, a plurality of pulse-height shaper amplifiers (PHSA) **404**, **406**, **408**, **410**, **412**, **414**, **416**, and **418**, a plurality of analog-to-digital (A-to-D) converters **420**, **422**, **424**, **426**, **428**, **430**, **432**, **434**, and **436**, a plurality of spectrum memory circuits (SMCs) **438**, **440**, **442**, **444**, **446**, **448**, **450**, **452**, and **454** allowing pulse height spectra to be acquired, a plurality of correction devices (CDs) **456**, **458**, **460**, **462**, **464**, **466**, **468**, and **470**, processor **190**, input device **192**, display device **194**, and memory device **195**. An example of each of correction devices **456**, **458**, **460**, **462**, **464**, **466**, **468**, and **470** include a divider circuit. Each of spectrum memory circuits **438**, **440**, **442**, **444**, **446**, **448**, **450**, **452**, and **454** include an adder and a memory device, such as a RAM or a ROM.

Transmission detector element **21** generates an electrical output signal **496** by detecting primary beam **84** and scatter detector elements **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54** generate a plurality of electrical output signals **498**, **500**, **502**, **504**, **506**, **508**, **510**, and **512** by detecting scattered radiation. For example, transmission detector element **21** generates electrical output signal **496** for x-ray photons incident on transmission detector element **21**. Scatter detector elements **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54** are coupled to pulse-height shaper amplifiers **404**, **406**, **408**, **410**, **412**, **414**, **416**, and **418**, respectively. Each pulse-height shaped amplifier amplifies an electrical output signal received from a detector element. For example, pulse-height shaper amplifier **404** amplifies electrical output signal **498**. Pulse-height shaper amplifiers **404**, **406**, **408**, **410**, **412**, **414**, **416**, and **418** have a gain factor determined by processor **190**.

An amplitude of an electrical output signal output from a detector element is proportional to an energy of an x-ray quantum that is detected by the detector element to generate the electrical output signal. For example, an amplitude of electrical output signal **496** is proportional to an energy of an x-ray quantum in primary beam **84** detected by detector element **21**. As another example, an amplitude of electrical output signal **498** is proportional to an energy of an x-ray quantum within scattered radiation that is detected by detector element **40**.

A pulse-height shaper amplifier generates an amplified output signal by amplifying an electrical output signal generated from a detector element. For example, pulse-height shaper amplifier **404** generates an amplified output signal **516** by amplifying electrical output signal **498** and pulse-height shaper amplifier **406** generates an amplified output signal **518** by amplifying electrical output signal **500**. Similarly, a plurality of amplified output signals **518**, **520**, **522**, **524**, **526**, **528**, and **530** are generated. An analog-to-digital converter converts an output signal from an analog form to a digital form to generate a digital output signal. For example, analog-to-digital converter **420** converts electrical output signal **496** from an analog form to a digital format to generate a digital output signal **532** and analog-to-digital converter **422** converts amplified output signal **516** from an analog form to a digital format to generate a digital output signal **534**. Similarly, a plurality of digital output signals **536**, **538**, **540**, **542**, **544**, **546**, and **548** are generated by analog-to-digital converters **424**, **426**, **428**, **430**, **432**, **434**, and **436**, respectively. A digital value of a digital output signal generated by an analog-to-digital converter represents an amplitude of energy or alternatively an amplitude of intensity of a pulse of an amplified output signal. Each pulse is generated by an x-ray quantum, such as an x-ray photon. For example, a digital value of digital output signal **534** output by analog-to-digital converter **422** is a value of an amplitude of a pulse of amplified output signal **516**.

An adder of a spectrum memory circuit adds a number of pulses in a digital output signal. For example, when analog-to-digital converter **422** converts a pulse of amplified output signal **516** into digital output signal **534** to determine an amplitude of the pulse of amplified output signal **516**, an adder within spectrum memory circuit **440** increments, by one, a value within a memory device of spectrum memory circuit **440**. Accordingly, at an end of an x-ray examination of substance **82**, a memory device within a spectrum memory circuit stores a number of x-ray quanta detected by a detector element. For example, a memory device within spectrum memory circuit **442** stores a number of x-ray photons detected by detector element **42** and each of the x-ray photons has an amplitude of energy that is determined by analog-to-digital converter **424**.

A correction device receives a number of x-ray quanta that have a range of energies and are stored within a memory device of one of spectrum memory circuits **440**, **442**, **444**, **446**, **448**, **450**, **452**, and **454**, and divides the number by a number of x-ray quanta having the range of energies received from a memory device of spectrum memory circuit **438**. For example, correction device **456** receives a number of x-ray photons having a range of energies from a memory device of spectrum memory circuit **440**, and divides the number by a number of x-ray photons having the range received from a memory device of spectrum memory circuit **438**. Each correction device outputs a correction output signal that represents a range of energies within x-ray quanta received by a detector element. For example, correction device **456** outputs a correction output signal **580** representing an energy spectrum or alternatively an intensity spectrum within x-ray quanta detected by detector element **40**. As another example, correction device **458** outputs correction output signal **582** representing an energy spectrum within x-ray quanta detected by detector element **42**. Similarly, a plurality of correction output signals **584**, **586**, **588**, **590**, **592**, and **594** are generated by correction devices **460**, **462**, **464**, **466**, **468**, and **470**, respectively.

Processor **190** receives correction output signals **280**, **282**, **284**, **286**, **288**, **290**, **292**, **294**, **580**, **582**, **584**, **586**, **588**, **590**, **592**, and **594** to generate a momentum transfer $x_A$, measured in inverse nanometers ($nm^{-1}$), from an energy spectrum $r(E_A)$ of energy $E_A$ of x-ray quanta within scattered radiation detected by scatter detectors **16** and **18** (FIG. **1**). Processor **190** generates the momentum transfer $x_A$ by applying

$$x_A=(E_A/hc)\sin(\theta/2) \quad (1)$$

where c is a speed of light, h is Planck's constant, θ represents constant scatter angles of x-ray quanta of scattered radiation detected by scatter detectors **16** and **18** (FIG. **1**). Examples of θ include scatter angles **96** and **97** (FIG. **1**). Processor **190** relates the energy $E_A$ to the momentum transfer $x_A$ by equation (1). Mechanical dimensions of secondary collimator **76** (FIG. **1**) defines the scatter angle θ. The secondary collimator **76** (FIG. **1**) restricts scattered radiation that does not have the angle θ. Processor **190** receives the scatter angle θ from a user, such as a human being, via input device **192**. Processor **190** generates a diffraction profile of substance **82** (FIG. **1**) by calculating a number of scatter x-ray photons that are detected by scatter detectors **16** and **18** and by plotting the number versus the momentum transfer $x_A$.

It is noted that a number of pulse-height shape amplifiers **404**, **406**, **408**, **410**, **412**, **414**, **416**, and **418** changes with a number of scatter detector elements **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54**. For example, five pulse-height shaper amplifiers are used for amplifying signals received from five scatter detector elements. As another example, four pulse-height shaper amplifiers are used for amplifying signals received from four scatter detector elements. Similarly, a number of analog-to-digital converters **420**, **422**, **424**, **426**, **428**, **430**, **432**, **434**, and **436** changes with a number of detector elements **21**, **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54**, and a number of spectrum memory circuits **438**, **440**, **442**, **444**, **446**, **448**, **450**, **452**, and **454** changes with the number of detector elements **21**, **40**, **42**, **44**, **46**, **48**, **50**, **52**, and **54**.

FIG. **4** is a diagram of an embodiment of a system **600** for generating an x-ray image. System **600** includes a gantry **602**, processor **190**, input device **192**, display device **194**, and memory device **195**. Gantry **602** is an example of gantry **12** (FIG. **1**). Gantry **602** includes a power supply **604**, an x-ray generation control unit **606**, x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, a data acquisition system (DAS) **608**, and transmission detector **17**. Alternatively, power supply **604** is located outside gantry **602**.

X-ray generation control unit **606** includes a pulse generator (not shown) that is coupled to processor **190** and that receives power from power supply **604**. Power supply **604** is coupled to x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** to supply power to x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**.

Processor **190** issues a command, such as a first on command, a second on command, a first off command, and a second off command. Upon receiving the first on command from processor **190**, the pulse generator generates a pulse and transmits the pulse to x-ray source **66**. Upon receiving a pulse from the pulse generator, x-ray source **66** generates x-ray beam **67** under a potential applied by power supply **604**. Similarly, upon receiving the first off command signal from processor **190**, the pulse generator stops transmitting a pulse to x-ray source **66** and x-ray source **66** stops generating x-ray beam **67**. Furthermore, upon receiving the second on command signal from processor **190**, the pulse generator generates and transmits a pulse to any one of the remaining x-ray sources **60**, **62**, **64**, **68**, **70**, **72**, and **74** and any one of the remaining x-ray sources **60**, **62**, **64**, **68**, **70**, **72**, and **74** generates an x-ray beam. For example, upon receiving the second on command signal from processor **190**, the pulse generator generates and transmits a pulse to x-ray source **64** and x-ray source **64** generates an x-ray beam **610**. Upon receiving the second off command signal from processor **190**, the pulse generator stops transmitting a pulse to any one of the remaining x-ray sources **60**, **62**, **64**, **68**, **70**, **72**, and **74** and the one of the remaining x-ray sources **60**, **62**, **64**, **68**, **70**, **72**, and **74** stops generating an x-ray beam.

DAS **608** samples analog data, such as electrical output signals, generated from a plurality of detector elements, including detector elements **20** and **21**, of transmission detector **17** and converts the analog data to a plurality of digital signals for subsequent processing.

FIG. **5** is an isometric view of an alternative embodiment of a system **700** for generating a diffraction profile of a substance. System **700** includes a gantry **702**. Gantry **702** includes x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, primary collimator **14**, secondary collimator **76**, scatter detectors **16** and **18**, transmission detector **17**, a secondary collimator **704**, and a plurality of scatter detectors **708** and **710** that detect coherent scatter. Gantry **702** is an example of gantry **12** (FIG. **1**). Secondary collimator **704** has the same structure as that of secondary collimator **76**. Scatter detectors **708** and **710** are located on a side of transmission detector **17** and the side is opposite to a side where scatter detectors **16** and **18** are located. A number of scatter detectors on a side, with respect to transmission detector **17**, of placement of scatter detectors **16** and **18** is the same as a number of scatter detectors on a side, with respect to transmission detector **17**, of placement of scatter detectors **708** and **710**. For example, if five scatter detectors are placed on one side of transmission detector **17** where scatter detectors **16** and **18** are placed, five scatter detectors are placed on the other side of transmission detector **17** where scatter detectors **708** and **710** are placed. A shortest distance between a center of scatter detector **708** and a center of scatter detector **710** is the same as shortest distance **56** between a center of scatter detector **16** and a center of scatter detector **18**. Scatter detectors **708** and **710** are separated from each other by a gap. Each scatter detector **708** and **710** has the same number of detector elements as scatter detector **16**. A shortest distance of transmission detector **17** from any of scatter detectors **16**, **18**, **708**, and **710** is the same. For example, a shortest distance of transmission detector **17** from scatter detector **708** is equal to the shortest distance of transmission detector **17** from scatter detector **18**.

Primary beams **83** and **84** pass through points **85** and **86** on substance **82** to generate scattered radiation **88** (FIG. **1**), **89** (FIG. **1**), **90** (FIG. **1**), **91** (FIG. **1**), **712**, **714**, **716**, and **718**. For example, primary beam **83** passes through point **85** on substance **82** to generate scattered radiation **88** (FIG. **1**), **89** (FIG. **1**), **712** and **714**. As another example, primary beam **84** passes through point **86** on substance **82** to generate scattered radiation **90** (FIG. **1**), **91** (FIG. **1**), **716** and **718**.

Secondary collimator **704** is located between support **80** and a set of scatter detectors **708** and **710**. Secondary collimator **704** includes a number of collimator elements to ensure that scattered radiation arriving at scatter detectors **708** and **710** have constant scatter angles with respect to primary beams **83** and **84** and that a position of scatter detectors **708** and **710** permits a depth in container **79** at which the scattered radiation originated to be determined. For example, the collimator elements of secondary collimator **704** are arranged parallel to a direction of scattered radiation **712** and of scattered radiation **716** to absorb scattered radiation that is not parallel to the direction of scattered radiation **712** and of scattered radiation **716**.

The number of collimator elements in secondary collimator **704** provided is equal to or alternatively greater than a number of detector elements of one of scatter detectors **708** and **710** and the collimator elements are arranged such that scattered radiation between neighboring collimator elements is incident on one of the detector elements. The collimator elements of scatter detectors **708** and **710** are made of a radiation-absorbing material, such as, a copper alloy or a silver alloy.

Underneath support **80**, there are arranged scatter detectors **708** and **710** that measure photon energies of scattered radiation detected by scatter detectors **708** and **710**. Scatter detectors **16**, **18**, transmission detector **17**, and scatter detectors **708** and **710** lie in the same yz plane. Each of scatter detectors **708** and **710** measures the x-ray photons within scattered radiation in an energy-sensitive manner by outputting a plurality of electrical output signals linearly dependent on a plurality of energies of the x-ray photons detected from within scattered radiation. Scatter detector **708** measures scattered radiation **712** received at a point **720** on scatter detector **708** and scatter detector **710** measures scattered radiation **716** received at a point **722** on scatter detector **710**. An example of a shortest distance between points **85** and **720** includes a distance ranging from and including 900 mm to 1100 mm. An example of a distance between points **720** and **92** includes a distance ranging from and including 25 mm to 45 mm.

Scatter detectors **708** and **710** detect scattered radiation to generate a plurality of electrical output signals. Scatter detector **708** detects scattered radiation **712** generated upon intersection of primary beam **83** with point **85**. Moreover, scatter detector **708** detects scattered radiation **718** generated upon intersection of primary beam **84** with point **86**. Scatter detector **710** detects scattered radiation **716** generated upon intersection of primary beam **84** with point **86**. Moreover, scatter detector **710** detects scattered radiation **714** generated upon intersection of primary beam **83** with point **85**. A scatter angle **724** formed between primary beam **83** and scattered radiation **712** is equal to a scatter angle **726** formed between primary beam **84** and scattered radiation **716**. An example of each of scatter angles **724** and **726** includes an angle ranging from and including 0.025 radians to 0.045 radians. An example of a scatter angle **728** formed between primary beam **83** and scattered radiation **714** ranges from and including 0.05 radians to 0.09 radians. Moreover, an example of a scatter angle **729** formed between primary beam **84** and scattered radiation **718** ranges from and including 0.05 radians to 0.09 radians. Scatter angle **728** is at least twice of each scatter angle **724** and **726** and scatter angle **729** is at least twice of each scatter angle **724** and **726**. Angle **99** formed by primary beam **83** with respect to center **101** between scatter detectors **708** and **710** is equal to angle **103** formed by primary beam **84** with respect to center **101**. In an alternative embodiment, system **700** does not include secondary collimators **76** and **704**.

Scatter detector **708** is connected to a system similar to system **100** (FIG. **2**) to generate a plurality of correction output signals, such as correction output signals **280**, **282**, **284**, **286**, **288**, **290**, **292**, and **294** (FIG. **2**). Moreover, scatter detector **710** is connected to a system similar to system **400** (FIG. **3**) to generate a plurality of correction output signals, such as correction output signals **580**, **582**, **584**, **586**, **588**, **590**, **592**, and **594** (FIG. **3**). Processor **190** receives correction output signals **280**, **282**, **284**, **286**, **288**, **290**, **292**, **294**, **580**, **582**, **584**, **586**, **588**, **590**, **592**, and **594** (FIGS. **2** and **3**), the correction output signals generated by the system that is similar to system **100** (FIG. **2**) and that is connected to scatter detector **708**, and the correction output signals generated by the system that is similar to system **400** (FIG. **3**) and that is connected to scatter detector **710**, to generate a momentum transfer $x_B$.

Processor **190** generates the momentum transfer $x_B$, measured in $nm^{-1}$, from an energy spectrum $r(E_B)$ of energy $E_B$ of x-ray quanta within scattered radiation detected by scatter detectors **16**, **18**, **708**, and **710**. Processor **190** generates the momentum transfer $x_B$ by applying

$$x_B=(E_B/hc)\sin(\theta/2) \tag{2}$$

where c is a speed of light, h is Planck's constant, θ represents constant scatter angles of x-ray quanta of scattered radiation detected by scatter detectors **16**, **18**, **708**, and **710**. Examples of θ include scatter angles **96** (FIG. **1**), **97** (FIG. **1**), **724**, and **726**. Processor **190** relates the energy $E_B$ to the momentum transfer $x_B$ by equation (2). The secondary collimators **76** (FIG. **1**) and **704** restrict scattered radiation that does not have the angle θ. Processor **190** generates a diffraction profile of substance **82** by calculating a number of scatter x-ray photons that are detected by scatter detectors **16**, **18**, **708** and **710**, and by plotting the number versus the momentum transfer $x_B$.

FIG. **6** is a diagram of illustrating an embodiment of a virtual system **900** for developing a primary collimator. Processor **190** generates virtual system **900**. For example, processor **190** generates virtual system **900** to display virtual system **900** on display device **194** (FIG. **2**). Virtual system **900** includes a plurality of virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922**, a plurality of virtual collimator elements **924**, **926**, and **928**, and a plurality of virtual detectors **930**, **932**, **934**, **936**, and **938**, such as virtual transmission detectors. Processor **190** generates virtual x-ray sources **906**, **908**, **910**, **912**, **914**, **916**, **918**, and **920** as a virtual representation of x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** (FIG. **1**) and locates virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** along a curve **940**. Processor **190** generates each of remaining virtual x-ray sources **902**, **904**, and **922** (FIG. **1**) as a virtual representation of an x-ray source, such as x-ray source **74**. Moreover, processor **190** generates virtual detector **934** as a virtual representation of transmission detector **17** (FIG. **1**). Processor **190** generates each of remaining virtual detectors **930**, **932**, **936**, and **938** as a virtual representation of a transmission detector, such as transmission detector **17**. Processor **190** generates a virtual opening **942** as a virtual representation of opening **65** (FIG. **1**).

The user provides an organization of the components of system **10** (FIG. **1**) to processor **190** via input device **192** (FIG. **2**). The user inputs, via input device **192**, a plurality of distances between the components of system and provides the organization of the components of system **10** to processor **190** by providing the distances to processor **190** via input device **192**. For example, the user specifies a number of detector elements within transmission detector **17**, a number of detector elements within each of scatter detectors **16** and **18**, a radius of arc **75**, a plurality of positions of x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** with respect to at least one of transmission detector **17**, scatter detector **16**, and scatter detector **18**, a distance between any two of x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, and a position of opening **65** with respect to at least one of transmission detector **17**, scatter detector **16**, and scatter detector **18**, and x-ray source **66**.

Processor **190** organizes the virtual elements of virtual system **900** and the organization is proportional, by a first factor, such as one-half or one-third, to the organization of the components of system **10** input by the user. For example, processor **190** generates any two of adjacent virtual x-ray sources from virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and a distance between the two adjacent virtual x-ray sources is proportional, such as one-half or one-third, to a distance between any two adjacent x-ray sources from x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**. As another example, processor **190** generates two adjacent virtual detectors from virtual detectors **930**, **932**, **934**, **936**, and **938** and a distance between the two adjacent virtual detectors is proportional to a distance between transmission detector **17** (FIG. **1**) and another transmission detector (not shown) adjacent to transmission detector **17** (FIG. **1**). As yet another example, processor **190** generates virtual x-ray source **912** and virtual detector **934**, and a distance between virtual x-ray source **912** and virtual detector **934** is proportional to a distance between x-ray source **66** and transmission detector **17**. As still another example, processor **190** generates virtual opening **942** and a distance between virtual opening **942** and virtual x-ray source **912** is proportional to a distance between x-ray source **66** and opening **65**. As a further example, processor **190** generates virtual detector **934** and a distance between virtual detector **934** and virtual opening **942** is proportional to a distance between transmission detector **17** and opening **65**.

Processor **190** extends a number, such as four or five, of virtual beams, which are straight lines, from each virtual x-ray source **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922**. Processor **190** extends the number of virtual beams and the number matches a number of virtual detectors **930**, **932**, **934**, **936**, and **938**. For example, processor **190** extends five virtual beams from each virtual x-ray source **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and upon organizing five virtual detectors **930**, **932**, **934**, **936**, and **938** within virtual system **900**. As another example, processor **190** extends four virtual beams from each virtual x-ray source **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and upon organizing four virtual detectors within virtual system **900**.

Processor **190** extends the number of virtual beams from each virtual x-ray source **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and each virtual detector **930**, **932**, **934**, **936**, and **938** receives one of the virtual beams. For example, processor **190** extends a virtual beam **944**, as a straight line, from virtual x-ray source **902** and virtual detector **930** receives virtual beam **944**. As another example, processor **190** extends a virtual beam **946**, as a straight line, from virtual x-ray source **902** and virtual detector **932** receives virtual beam **946**. As yet another example, processor **190** extends a virtual beam **948**, as a straight line, from virtual x-ray source **902** and virtual detector **934** receives virtual beam **948**. As still another example, processor **190** extends a virtual beam **950**, as a straight line, from virtual x-ray source **920** and processor **190** and virtual detector **938** receives virtual beam **950**. As another example, processor **190** extends a virtual beam **952**, as a straight line, from virtual x-ray source **920** and virtual detector **936** receives virtual beam **952**. As yet another example, processor **190** extends a virtual beam **954**, as a straight line, from virtual x-ray source **920** and virtual detector **934** receives virtual beam **954**.

Processor **190** determines a number of virtual points between virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and virtual detectors **930**, **932**, **934**, **936**, and **938** and a maximum number, such as 5 or 6, of virtual beams intersect each other at each of the virtual points. As an example, processor **190** determines that five virtual beams from virtual x-ray sources **904**, **906**, **908**, **910**, and **912** intersect each other at a virtual point **956**. As another example, processor **190** determines that five virtual beams from virtual x-ray sources **906**, **908**, **910**, **912**, and **914** intersect each other at a virtual point **958**. The maximum number is equal to the number of virtual beams output by each virtual x-ray source **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922**. Similarly, processor **190** determines virtual points **960** and **962**. Processor **190** generates an axis **955** that extends through virtual points **956**, **958**, **960**, and **962**. Processor **190** generates virtual collimator element **928** that coincides with axis **955** at a plurality of virtual points, such as virtual points **956**, **958**, **960**, and **962**. In an alternative embodiment, processor **190** generates a lower or alternatively a higher number of virtual points on axis **955** than a number of virtual points **956**, **958**, **960**, and **962**.

Processor **190** determines a number of virtual points between virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and virtual detectors **930**, **932**, **934**, **936**, and **938** and a number, such as three, lower than the maximum number, of virtual beams intersect each other at each of the virtual points. As an example, processor **190** determines that three virtual beams from virtual x-ray sources **906**, **908**, and **910** intersect each other at a virtual point **964**. As another example, processor **190** determines that three virtual beams from virtual x-ray sources **908**, **910**, and **912** intersect each other at a virtual point **966**. Similarly, processor **190** determines virtual points **968**, **970**, and **972**. Processor **190** generates an axis **963** that extends through virtual points **964**, **966**, **968**, **970**, and **972**. Processor **190** generates virtual collimator element **926** that coincides with axis **963** at a plurality of virtual points, such as virtual points **964**, **966**, **968**, **970**, and **972**. As yet another example, processor **190** determines that two virtual beams from virtual x-ray sources **904** and **906** intersect each other at a virtual point **974**. As another example, processor **190** determines that two virtual beams from virtual x-ray sources **906** and **908** intersect each other at a virtual point **976**. Similarly, processor **190** determines virtual points **978** and **980**. Processor **190** generates an axis **982** that extends through virtual points **974**, **976**, **978**, and **980**. Processor **190** collates the intersection points to find those which pass through approximately the same x-position. Processor **190** generates virtual collimator element **924** that coincides with axis **982** at a plurality of virtual points, such as virtual points **974**, **976**, **978**, and **980**. Virtual collimator element **928** is closest to virtual opening **942** than the remaining virtual collimator elements **924** and **926**. In an alternative embodiment, processor **190** generates a lower or alternatively a higher number of virtual points on axis **963** than a number of virtual points **964**, **966**, **968**, **970**, and **972**. In another alternative embodiment, **190** generates a lower or alternatively a higher number of virtual points on axis **982** than a number of virtual points **974**, **976**, **978**, and **980**.

Processor **190** generates virtual collimator elements **924**, **926**, and **928** and virtual collimator elements **924**, **926**, and **928** do not intersect virtual opening **942**. In an alternative embodiment, virtual collimator elements **924**, **926**, and **928** do not intersect container **79**. Processor **190** generates virtual collimator elements **924**, **926**, and **928** that lie between virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** and virtual opening **942**. Processor **190** determines a plurality of virtual positions, such as $x_{v1}$ and $y_{v1}$ virtual co-ordinates or $x_{v2}$ and $y_{v2}$ virtual co-ordinates or $x_{v3}$ and $y_{v3}$ virtual co-ordinates, of virtual collimator elements **924**, **926**, and **928** and determines a plurality of positions, such as $x_{v4}$ and $y_{v4}$ virtual co-ordinates, $x_{v5}$ and $y_{v5}$ virtual co-ordinates, $x_{v6}$ and $y_{v6}$ virtual co-ordinates, $x_{v7}$ and $y_{v7}$

virtual co-ordinates, $x_{v8}$ and $y_{v8}$ virtual co-ordinates, or $x_{v9}$ and $y_{v9}$ virtual co-ordinates, of virtual points on virtual collimator elements **924**, **926**, and **928**. For example, processor **190** determines the $x_{v1}$ and $y_{v1}$ virtual co-ordinates of virtual collimator element **928** with respect to an origin of an $x_v y_v z_v$ co-ordinate system. As another example, processor **190** determines the $x_{v4}$ and $y_{v4}$ virtual co-ordinates of virtual point **974** with respect to the origin of the $x_v y_v z_v$ co-ordinate system. The $x_v y_v z_v$ co-ordinate system is proportional to the xyz co-ordinate system shown in FIGS. **1**, **4**, and **5**. The $x_v y_v z_v$ co-ordinate system includes an $x_v$ axis, a $y_v$ axis, and a $z_v$ axis. The $x_v$ axis is perpendicular to the $y_v$ axis and the $z_v$ axis, and the $y_v$ axis is perpendicular to the $z_v$ axis.

It is noted that virtual collimator elements **924**, **926**, and **928** are curved and that none of virtual collimator elements **924**, **926**, and **928** are circular in shape. It is also noted that in an alternative embodiment, processor **190** generates virtual collimator element **928** and does not generate any other virtual collimator element. In yet another alternative embodiment, processor **190** generates any number, such as 2, 3, 4, or 5, of virtual collimator elements.

FIG. **7** is a diagram of an embodiment of a system **1000** implementing a primary collimator. System **1000** is an example of system **10** (FIG. **1**) and system **600** (FIG. **4**). Alternatively, system **1000** is an example of system **700** (FIG. **5**). System **1000** includes gantry **12**. Gantry **12** includes opening **65**, x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**, a plurality of primary collimator elements **1002**, **1004**, and **1006**, and a plurality of holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018**. An example of each of primary collimator elements **1002**, **1004**, and **1006** include a sheet or a lamination. Primary collimator elements **1002**, **1004**, and **1006** are fabricated from a material, such as molybdenum or tungsten. Holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018** are fabricated from a metal, such as steel or aluminum. Primary collimator elements **1002**, **1004**, and **1006** are located between x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** and opening **65**, and collectively form primary collimator **14** (FIG. **1**). As an example, each primary collimator element **1002**, **1004**, and **1006** has a length ranging from and including 1 meters (m) to 1.5 meters in the y-direction, ranging from and including 0.5 millimeters (mm) to 5 mm in the z-direction, and ranging from and including 2.5 mm to 5.5 mm in the x-direction.

Primary collimator element **1002** is supported by holders **1008** and **1014**. Primary collimator element **1004** is support by holders **1010** and **1016**, and primary collimator element **1006** is supported by holders **1012** and **1018**. Holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018** are attached by a connection process, such as gluing or spot welding, to a plurality of side walls **1020** and **1022** of gantry **12**. For example, holders **1008**, **1010**, and **1012** are attached to side wall **1020** and holders **1014**, **1016**, and **1018** are attached to side wall **1022**. Alternatively, holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018** are attached to side walls **1020** and **1022** by fitting holders **1008**, **1010**, and **1012** to side wall **1020** via a plurality of screws and by fitting holders **1014**, **1016**, and **1018** to side wall **1022** via a plurality of screws. Each of holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018** include a slot that extends in the z-direction. For example, holder **1008** includes a slot **1024**, holder **1010** includes a slot **1026**, holder **1012** includes a slot **1028**, holder **1014** includes a slot **1030**, holder **1016** includes a slot **1032**, and holder **1018** includes a slot **1034**.

The user fabricates holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018** and slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034** by using a molding machine having a plurality of peaks of a shape of any of slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034**, filling a liquid metal, such as steel, within the molding machine, and cooling the metal to create slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034** within holders **1008**, **1010**, **1012**, **1014**, **1016**, and **1018**. Alternatively, the user creates slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034** by operating an etching machine to develop slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034**. Each of slots **1024**, **1026**, **1028**, **1030**, **1032**, and **1034** have a plurality of dimensions that are slightly larger than a plurality of dimensions of each of primary collimator elements **1002**, **1004**, and **1006**. For example, if primary collimator element **1002** has a dimension along the x-axis of 5 mm, slot **1024** has a dimension along the x-axis of more than 5 mm, such as 5.2 mm. As another example, if primary collimator element **1002** has a dimension along the y-axis of 1.2 m, slot **1024** has a dimension along the y-axis of more than 1.2 m, such as 1.5 m. As yet another example, if primary collimator element **1002** has a dimension along the z-axis of 1 mm, slot **1024** has a dimension along the y-axis of more than 1.2 mm, such as 1.5 mm.

The user slides a primary collimator element within slots to use holders to support primary collimator element. For example, the user slides, in the z-direction, primary collimator element **1002** within slot **1024** of holder **1008** and slot **1030** of holder **1014** to use holders **1008** and **1014** to support primary collimator element **1002**. As another example, the user slides, in the z-direction, primary collimator element **1004** within slot **1026** of holder **1010** and slot **1032** of holder **1016** to use holders **1010** and **1016** to support primary collimator element **1004**.

Processor **190** calculates a plurality of positions, such as $x_1$ and $y_1$ co-ordinates, $x_2$ and $y_2$ co-ordinates, or $x_3$ and $y_3$ co-ordinates, of primary collimator elements **1002**, **1004**, and **1006** within gantry **12** as being proportional, by a second factor, such as 2 or 3, to the virtual positions of virtual collimator elements **924**, **926**, and **928**. For example, processor **190** multiplies the co-ordinates $x_{v1}$ and $y_{v1}$ co-ordinates of virtual collimator element **928** with the second factor to generate the $x_1$ and $y_1$ co-ordinates of primary collimator element **1006**. As another example, processor **190** multiplies the $x_{v2}$ and $y_{v2}$ co-ordinates of virtual collimator element **926** with the second factor to generate the $x_2$ and $y_2$ co-ordinates of primary collimator element **1004**. As yet another example, processor **190** multiplies the $x_{v3}$ and $y_{v3}$ co-ordinates of virtual collimator element **924** with the second factor to generate the co-ordinates $x_3$ and $y_3$ of primary collimator element **1002**. The second factor is an inverse of the first factor. For example, if the first factor is one-half, the second factor is 2.

Virtual collimator element **924** (FIG. **6**) is a virtual representation of primary collimator element **1002**, virtual collimator element **926** (FIG. **6**) is a virtual representation of primary collimator element **1004**, and virtual collimator element **928** (FIG. **6**) is a virtual representation of primary collimator element **1006**. Primary collimator **14** includes any number, such as 2, 3, or 4, of primary collimator elements, such as primary collimator elements **1002**, **1004**, and **1006**. Primary collimator element **1006** has a minimum number of apertures compared to a number of apertures in either primary collimator element **1002** or primary collimator element **1004**. It is advantageous to have primary collimator element **1006** with the minimum number of apertures. The minimum number of apertures depends on a size of container **79** and a number of x-ray sources for scanning container **79**.

FIG. **8** is a top view of an embodiment of gantry **12**. Gantry **12** includes primary collimator element **1002** and holders **1008** and **1014**. Primary collimator element **1002** includes a plurality of apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, and **1054**. A number of apertures within primary collimator element **1002** is equal to a number of virtual points on virtual collimator element **924**. Processor **190** outputs a plurality of positions, such as the co-ordinates $x_4$ and $y_4$, of apertures within primary collimator element **1002** as being proportional by the second factor to the positions of virtual points of virtual collimator element **924**. For example, processor **190** multiplies the virtual co-ordinates $x_{v4}$ and $y_{v4}$ of virtual point **974** with the second factor to generate the co-ordinates $x_4$ and $y_4$ of aperture **1042** of primary collimator element **1002**. As another example, processor **190** multiplies the co-ordinates $x_{v5}$ and $y_{v5}$ of virtual point **976** with the second factor to generate a plurality of co-ordinates $x_5$ and $y_5$ of aperture **1044** of primary collimator element **1002**.

Slot **1024** has a length in the z-direction greater than a length of primary collimator element **1002** in the z-direction. For example, slot **1024** extends, within holder **1008**, from a point **1056** to a point **1058**, along the z-direction and primary collimator element **1002** extends from a point **1060** to point **1058**, along the z-direction. A distance, in the z-direction, between points **1058** and **1060** is less than a distance, in the z-direction, between points **1056** and **1058**. The user slides, in the z-direction, primary collimator element **1002** from a side **1062** of holder **1008** into slot **1024** and from a side **1064** of holder **1014** into slot **1030** to locate primary collimator element **1002** within slots **1024** and **1030**.

FIG. **9** is a top view of an embodiment of gantry **12**. Gantry **12** includes primary collimator element **1004** and holders **1010** and **1016**. Primary collimator element **1004** includes a plurality of apertures **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, and **1084**. A number of apertures within primary collimator element **1004** is equal to a number of virtual points on virtual collimator element **926**. Processor **190** outputs a plurality of positions, such as the co-ordinates $x_6$ and $y_6$, of apertures **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, and **1084** within primary collimator element **1004** as being proportional by the second factor to the virtual positions of virtual points of virtual collimator element **926** (FIG. **6**). For example, processor **190** multiplies the virtual co-ordinates $x_{v6}$ and $y_{v6}$ of virtual point **964** (FIG. **6**) with the second factor to generate the co-ordinates $x_6$ and $y_6$ of aperture **1074** of primary collimator element **1004**. As another example, processor **190** multiplies the co-ordinates $x_{v7}$ and $y_{v7}$ of virtual point **966** (FIG. **6**) with the second factor to generate a plurality of co-ordinates $x_7$ and $y_7$ of aperture **1076** of primary collimator element **1004**.

Slot **1026** has a length in the z-direction greater than a length of primary collimator element **1004** in the z-direction. For example, slot **1026** extends, within holder **1010**, from a point **1086** to a point **1088**, along the z-direction and primary collimator element **1004** extends from a point **1090** to point **1088**, along the z-direction. A distance, in the z-direction, between points **1088** and **1090** is less than a distance, in the z-direction, between points **1086** and **1088**. The user slides, in the z-direction, primary collimator element **1004** from a side **1092** of holder **1010** into slot **1026** and from a side **1094** of holder **1016** into slot **1032** to locate primary collimator element **1004** within slots **1026** and **1032**.

FIG. **10** is a top view of an embodiment of gantry **12**. Gantry **12** includes primary collimator element **1006** and holders **1012** and **1018**. Primary collimator element **1006** includes a plurality of apertures **1200**, **1202**, **1204**, **1206**, **1208**, **1210**, **1212**, and **1214**. A number of apertures within primary collimator element **1006** is equal to a number of virtual points on virtual collimator element **928**. Processor **190** outputs a plurality of positions, such as the co-ordinates $x_8$ and $y_8$, of apertures **1200**, **1202**, **1204**, **1206**, **1208**, **1210**, **1212**, and **1214** within primary collimator element **1006** as being proportional by the second factor to the virtual positions of virtual points of virtual collimator element **928**. For example, processor **190** multiplies the virtual co-ordinates $x_{v8}$ and $y_{v8}$ of virtual point **956** with the second factor to generate the co-ordinates $x_8$ and $y_8$ of aperture **1202** of primary collimator element **1006**. As another example, processor **190** multiplies the co-ordinates $x_{v9}$ and $y_{v9}$ of virtual point **958** with the second factor to generate a plurality of co-ordinates $x_9$ and $y_9$ of aperture **1204** of primary collimator element **1006**.

Slot **1028** has a length in the z-direction greater than a length of primary collimator element **1006** in the z-direction. For example, slot **1028** extends, within holder **1012**, from a point **1216** to a point **1218**, along the z-direction and primary collimator element **1006** extends from a point **1220** to point **1218**, along the z-direction. A distance, in the z-direction, between points **1218** and **1220** is less than a distance, in the z-direction, between points **1216** and **1218**. The user slides, in the z-direction, primary collimator element **1006** from a side **1222** of holder **1012** into slot **1028** and a side **1224** of holder **1018** into slot **1034** to locate primary collimator element **1006** within slots **1028** and **1034**.

The user creates apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, **1054**, **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, **1084**, **1200**, **1202**, **1204**, **1206**, **1208**, **1210**, **1212**, and **1214** (FIGS. **8-10**) by applying a process, such as a molding process. For example, the user creates apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, and **1054** of primary collimator element **1002** by using a molding machine having a plurality of peaks of a shape of any of apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, and **1054**, filling a metal, such as tungsten or molybdenum, within the molding machine, and cooling the metal to create apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, and **1054**. As an example, each aperture **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, **1054**, **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, **1084**, **1200**, **1202**, **1204**, **1206**, **1208**, **1210**, **1212**, and **1214** (FIGS. **8-10**) has a width ranging from and including 0.5 mm to 1.5 mm in the y-direction, a depth ranging from and including 0.1 mm to 0.5 mm in the z-direction, and a thickness ranging from and including 2.5 mm to 5.5 mm in the x-direction. A thickness of each aperture in the x-direction is the same as a thickness, in the x-direction, of a primary collimator element that includes the aperture. For example, a thickness of aperture **1040** in the x-direction is the same as a thickness of primary collimator element **1002** in the x-direction. The user creates apertures **1040**, **1042**, **1044**, **1046**, **1048**, **1050**, **1052**, **1054**, **1070**, **1072**, **1074**, **1076**, **1078**, **1080**, **1082**, **1084**, **1200**, **1202**, **1204**, **1206**, **1208**, **1210**, **1212**, and **1214** as having the same location, along the z-axis, as that of x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** (FIG. **1**) along the z-axis.

When x-ray beam **67** (FIG. **1**) passes through primary collimator **14**, primary collimator **14** collimates x-ray beam **67** to generate primary beams **83** and **84** (FIG. **1**) from two apertures **1046** and **1048** (FIG. **8**), respectively. Alternatively or in addition, when x-ray beam **67** (FIG. **1**) passes through primary collimator **14**, primary collimator **14** collimates x-ray beam **67** to generate primary beams **83** and **84** (FIG. **1**) from two apertures **1076** and **1078** (FIG. **9**), respectively. Moreover, alternatively or in addition, when x-ray beam **67** (FIG. **1**) passes through primary collimator **14**, primary collimator **14** collimates x-ray beam **67** to generate primary beams **83** and **84** (FIG. **1**) from two apertures **1206** and **1208**, respectively. Each aperture outputs a primary beam. For example, aperture **1072** (FIG. **9**) outputs a primary beam. As another example, aperture **1200** outputs a primary beam.

It is noted that an additional primary collimator element (not shown) is included within primary collimator **14** and coincides with points corresponding to a plurality of virtual points other than virtual points at which at least two beams from virtual x-ray sources **902**, **904**, **906**, **908**, **910**, **912**, **914**, **916**, **918**, **920**, and **922** intersect. The additional primary collimator element is parallel to any one of primary collimator elements **1002**, **1004**, and **1006** and includes a plurality of apertures to allow x-rays from x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** to reach any of primary collimator elements **1002**, **1004**, and **1006**. In an alternative embodiment, primary collimator **14** does not include the additional primary collimator element.

FIG. **11** is a diagram of an alternative embodiment of a gantry **1302**. Gantry **1302** is an example of gantries **602** (FIG. **4**) and **702** (FIG. **5**). Gantry **1302** includes opening **65**, a plurality of holders **1304**, **1306**, **1308**, **1310**, **1312**, and **1314**, and primary collimator elements **1002**, **1004**, and **1006**. The user fabricates holders **1304**, **1306**, **1308**, **1310**, **1312**, and **1314** from a metal, such as steel or aluminum. For example, the user fabricates holders **1304**, **1306**, **1308**, **1310**, **1312**, and **1314** by using a molding machine including molds of a shape of any of holders **1304**, **1306**, **1308**, **1310**, **1312**, and **1314**, filling the molding machine with a liquid metal, such as steel, and cooling the liquid metal. The user attaches a primary collimator element to a plurality of top surfaces of holders by a process, such as spot welding or gluing, or alternatively by using screws. For example, the user attaches primary collimator element **1002** with holder **1304** by gluing a bottom surface **1316** of primary collimator element **1002** to a top surface **1318** of holder **1304** and gluing bottom surface **1316** of primary collimator element **1002** to a top surface **1320** of holder **1310**. As another example, the user attaches primary collimator element **1004** with holder **1306** by spot welding a bottom surface **1322** of primary collimator element **1004** with a top surface **1324** of holder **1306** and spot welding bottom surface of primary collimator element **1004** with a top surface **1326** of holder **1312**. Holders **1304**, **1306**, **1308**, **1310**, **1312**, and **1314** do not include slots. Alternatively, the user attaches a top surface of a primary collimator element with a plurality of bottom surfaces of holders. For example, the user attaches a top surface **1328** of primary collimator element **1006** with a bottom surface **1330** of holder **1308** and a bottom surface **1332** of holder **1314**.

FIG. **12** is a top view of an embodiment of gantry **1302**. Gantry **1302** includes a plurality of holders **1402** and **1404**, and a primary collimator element **1406**. Primary collimator element **1406** is an example of any of primary collimator elements **1002**, **1004**, and **1006** (FIG. **11**). Holders **1402** and **1404** are examples of holders **1304** and **1310** (FIG. **11**), respectively, if primary collimator element **1406** is an example of primary collimator element **1002**. Holders **1402** and **1404** are examples of holders **1306** and **1312** (FIG. **11**), respectively, if primary collimator element **1406** is an example of primary collimator element **1004**. Holders **1402** and **1404** are examples of holders **1308** and **1314** (FIG. **11**), respectively, if primary collimator element **1406** is an example of primary collimator element **1006**. Primary collimator element **1406** is attached to a top surface **1408** of holder and to a top surface **1410** of holder.

Technical effects of the herein described systems and methods for generating an improved diffraction profile include increasing a single-to-noise ratio detected by providing at least two scatter detectors, such as scatter detectors **16** and **18**, to detect scattered radiation. Other technical effects include examining by at least two scatter detectors, such as scatter detectors **16** and **18**, of container **79** that is larger than a container (not shown) examined by a single scatter detector. Yet other technical effect includes an improved coverage of container **79** with primary x-rays. Still other technical effects include providing an improved diffraction profile by measuring energy at points **94** and **95**. Yet other technical effects include a reduction in power consumed by x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74**. The reduction in power is achieved by using a plurality of scatter detectors, such as scatter detectors **16** and **18**, to detect scattered radiation. The power consumed by x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** to generate a diffraction profile having a certain quality is reduced compared to a power consumed by a plurality of x-ray sources to provide x-rays to a single scatter detector that is used to generate the diffraction profile of the same quality. For example, a plurality of x-ray sources consume a high amount, such as 90 kilowatts (kW), of power to acquire a number of scattered x-ray photons detected by a single scatter detector in a restricted scan time to generate a diffraction profile of the scattered x-ray photons. The high amount of power is higher than a low amount, such as at most half of the high amount, of power consumed by x-ray sources **60**, **62**, **64**, **66**, **68**, **70**, **72**, and **74** to acquire the number of scattered x-ray photons detected by at least two scatter detectors, such as scatter detectors **16** and **18**, in the restricted scan time.

The scatter angle **98** is larger than, such as at least twice compared to, scatter angle **96**. Energy of scattered x-ray photons scattered from point **85** onto scatter detector **18** is at least twice that of energy of scattered x-ray photons scattered from point **85** onto detector **16** at the same momentum transfer $x_A$. As a result, most of scattered x-ray photons from point **85** onto scatter detector **16** are absorbed by container **79**. Moreover, energy of scattered x-ray photons scattered from point **85** onto scatter detector **18** is at least twice that of energy of scattered x-ray photons scattered from point **86** onto scatter detector **18** at the same momentum transfer $x_A$. As a result, most of scattered x-ray photons from point **86** onto scatter detector **18** are absorbed by container **79**. Furthermore, energy of scattered x-ray photons scattered from point **85** onto scatter detector **708** is at least twice that of energy of scattered x-ray photons scattered from point **85** onto detector **710** at the same momentum transfer $x_B$. As a result, most of scattered x-ray photons from point **85** onto scatter detector **710** are absorbed by container **79**. Moreover, energy of scattered x-ray photons scattered from point **85** onto scatter detector **708** is at least twice that of energy of scattered x-ray photons scattered from point **86** onto detector **708** at the same momentum transfer $x_B$. As a result, most of scattered x-ray photons from point **86** onto scatter detector **708** are absorbed by container **79**. Energies, such as ranging from and including 30 kiloelectron volts (keV) to 200 keV, of scattered x-ray photons at scatter angle **98** detected by scatter detector **16** is lower than energies of scattered x-ray photons at scatter angle **96** detected by scatter detector **18**. As a result, most of scattered x-ray photons within scattered radiation **89** are attenuated by container **79**.

Moreover, scattered x-ray photons within scattered radiation **89** can be absorbed by a filter, such as a metal or a copper filter, placed between support **80** and secondary collimator **76**. Absorption of scattered x-ray photons within scattered radiation **89** by container **79** and/or the filter prevents an overload and a dead time of scatter detector **16**. Moreover, absorption of scattered x-ray photons within scattered radiation **89** by container **79** and/or the filter prevents an interference of the scattered x-ray photons with scattered radiation **88**.

While the invention has been described in terms of various specific embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the claims.

What is claimed is:

1. A system for generating a diffraction profile of an object, said system comprising:

at least one x-ray source configured to generate x-rays;

a primary collimator configured to divide the generated x-rays into a first x-ray beam directed to a first focus point within an object space and a second x-ray beam directed to a second focus point within the object space; and

a first scatter detector configured to:

detect a first set of scattered radiation generated upon intersection of the first x-ray beam with the object at a first point on said first scatter detector; and

detect a second set of scattered radiation generated upon intersection of the second x-ray beam with the object at the first point on said first scatter detector.

2. A system in accordance with claim 1, further comprising a second scatter detector separated by a gap from said first scatter detector, said second scatter detector configured to:

detect a third set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

detect a fourth set of scattered radiation generated upon intersection of the second x-ray beam with the object, the third set of scattered radiation and the fourth set of scattered radiation detected at a second point on said second scatter detector.

3. A system in accordance with claim 2, wherein an angle of scatter of the first set of scattered radiation detected by said first scatter detector is equal to an angle of scatter of the third set of scattered radiation detected by said second scatter detector.

4. A system in accordance with claim 1, wherein an angle of scatter of the first set of scattered radiation detected by said first scatter detector is at most one-half of an angle of scatter of the second set of scattered radiation detected by said first scatter detector.

5. A system in accordance with claim 2, further comprising:

a third scatter detector configured to detect a fifth set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

a fourth scatter detector configured to detect a sixth set of scattered radiation generated upon intersection of the second x-ray beam with the object.

6. A system in accordance with claim 1, further comprising a transmission detector configured to detect the first x-ray beam and the second x-ray beam.

7. A system in accordance with claim 5, further comprising:

a transmission detector configured to detect the first x-ray beam and the second x-ray beam; and

a gantry, wherein said transmission detector, said first scatter detector, said second scatter detector, said third scatter detector, and said fourth scatter detector are located within said gantry.

8. A system for generating a diffraction profile of an object, said system comprising:

at least one x-ray source configured to generate x-rays;

a primary collimator configured to divide the generated x-rays into a first x-ray beam directed to a first focus point within an object space and a second x-ray beam directed to a second focus point within the object space;

a first scatter detector configured to:

detect a first set of scattered radiation generated upon intersection of the first x-ray beam with the object at a first point on said first scatter detector; and

detect a second set of scattered radiation generated upon intersection of the second x-ray beam with the object at the first point on said first scatter detector; and

a processor coupled to said first scatter detector and configured to generate a portion of a diffraction profile of the object from the first set of scattered radiation and the second set of scattered radiation detected by said first scatter detector.

9. A system in accordance with claim 8, further comprising a second scatter detector separated by a gap from said first scatter detector, said second scatter detector configured to:

detect a third set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

detect a fourth set of scattered radiation generated upon intersection of the second x-ray beam with the object, the third set of scattered radiation and the fourth set of scattered radiation detected at a second point on said second scatter detector.

10. A system in accordance with claim 9, wherein an angle of scatter of the first set of scattered radiation detected by said first scatter detector is equal to an angle of scatter of the third set of scattered radiation detected by said second scatter detector.

11. A system in accordance with claim 9, further comprising:

a third scatter detector configured to detect a fifth set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

a fourth scatter detector configured to detect a sixth set of scattered radiation generated upon intersection of the second x-ray beam with the object.

12. A system in accordance with claim 11, further comprising a transmission detector configured to detect the first x-ray beam and the second x-ray beam, wherein said first and second scatter detectors are placed on a first side of said transmission detector, the first side is opposite to a second side of said transmission detector, and said third and fourth scatter detectors are placed on the second side.

13. A system in accordance with claim 9, further comprising:

a transmission detector configured to detect the first x-ray beam and the second x-ray beam; and

a gantry, wherein said transmission detector, said first scatter detector, and said second scatter detector are located within said gantry.

14. A system in accordance with claim 8, wherein an angle of scatter of the first set of scattered radiation detected by said first scatter detector is at most one-half of an angle of scatter of the second set of scattered radiation detected by said first scatter detector.

15. A method for generating a diffraction profile of an object, said method comprising:

generating x-rays by activating at least one x-ray source;

dividing the generated x-rays, using a primary collimator, into a first x-ray beam directed to a first focus point within an object space and a second x-ray beam directed to a second focus point within the object space;

detecting a first set of scattered radiation generated upon intersection of the first x-ray beam with the object at a first point on a first scatter detector; and

detecting a second set of scattered radiation generated upon intersection of the second x-ray beam with the object at the first point on the first scatter detector.

16. A method in accordance with claim 15, further comprising:

collimating the first set of scattered radiation for detection by the first scatter detector, the first set of scattered radiation collimated to impinge on the first scatter detector at the first point; and

collimating the second set of scattered radiation for detection by the first scatter detector, the second set of scattered radiation collimated to impinge on the first scatter detector at the first point.

**17**. A method in accordance with claim **15**, further comprising:

detecting, by a second scatter detector, a third set of scattered radiation generated upon intersection of the first x-ray beam with the object;

detecting, by the second scatter detector, a fourth set of scattered radiation generated upon intersection of the second x-ray beam with the object, the third set of scattered radiation and the fourth set of scattered radiation detected at a second point on the second scatter detector;

collimating the third set of scattered radiation for detection by the second scatter detector, the third set of scattered radiation collimated to impinge on the second scatter detector at the second point; and

collimating the fourth set of scattered radiation for detection by the second scatter detector, the fourth set of scattered radiation collimated to impinge on the second scatter detector at the second point.

**18**. A method in accordance with claim **17**, further comprising:

detecting, by a transmission detector, the first x-ray beam and the second x-ray beam;

detecting, by a third scatter detector, a fifth set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

detecting, by a fourth scatter detector, a sixth set of scattered radiation generated upon intersection of the second x-ray beam with the object, wherein the first and second scatter detectors are placed on a first side of the transmission detector, the first side is opposite to a second side of the transmission detector, and the third and fourth scatter detectors are placed on the second side.

**19**. A method in accordance with claim **17**, further comprising:

detecting, by a third scatter detector, a fifth set of scattered radiation generated upon intersection of the first x-ray beam with the object; and

detecting, by a fourth scatter detector, a sixth set of scattered radiation generated upon intersection of the second x-ray beam with the object.

**20**. A method in accordance with claim **19**, further comprising:

collimating the fifth set of scattered radiation for detection by the third scatter detector, the fifth set of scattered radiation collimated to impinge on the third scatter detector at a third point; and

collimating the sixth set of scattered radiation for detection by the fourth scatter detector, the sixth set of scattered radiation collimated to impinge on the fourth scatter detector at a fourth point.

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